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HUMAN BIOLOGY

a record of research

FEBRUARY, 1956

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32

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VOL. 28 No. 1

ESSAY ON A FUNDAMENTAL LAW OF LIFE THE TIME-FACTOR (RELATIVITY) IN BIOLOGICAL PHENOMENA

BY E. R. N. GRIGG
Kankakee, Illinois

A modern discourse on the essence of life (*i. e.*, what it is), particularly when reinforced with teleologic phraseology (*i. e.*, why it is as it is), can be more elaborate than a similar composition of antique vintage. It can also be more technical, by virtue of advances in biochemistry, but it cannot disguise our lack of knowledge in the matter. This unrewarding subject will be avoided in the following text, and the principle hereinafter considered pertains to the rules which shape the process of life (*i. e.*, how it evolves).

PROLEGOMENON

An ancient problem is the identification of life. The solution seems rather obvious in most instances yet the various signs proposed, be it the single Epicurean 'life is motion' or the plural Aristotelian 'food intake, growth, and withering,' reveal shortcomings in some aspect of

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life, *e. g.*, the latency stage of seeds. Even quite recently established criteria of vitality fail when applied to the borderline case of crystalline virus proteins.

One way to recognize a living organism could be the evaluation of its response to external influences, a phenomenon with both intrinsic and extrinsic circumstances. This implies an eclectic approach, for in the past the widely accepted dogma of a vital principle required a predominantly intrinsic orientation. The importance of ecologic factors, acknowledged at least since Hippocrates, has received proper emphasis only after mechanistic interpretations began to crowd the extrinsic horizon.

The first mention of *irritabilitas* of living tissues (*viz.*, imbued with vital spirits) can be found in Glisson (1677). Haller's famous experimental series on the contractility of muscles and sensibility of nerves, the theoretic elucubrations of the Brunonians, and the changing philosophical trend bridge the gap to Spencer's generalization that life is the adjustment of internal to external relations. Claude Bernard's *milieu intérieur* and Cannon's *homeostasis* are among the better known contributions to this idea of delicate equilibrium, maintained despite (or perhaps because of) constant disturbances.

FORMULATION

Since adaptation is but one of several possible responses, the range ought to be extended to make the principle all-inclusive: *life has* (or could even be defined tautologically as) *the tendency to eliminate the influence of environmental and internal agencies*. This is visually demonstrated during the microscopic examination of the reactions of *Daphnia magna* and other transparent animals to physical and chemical stimuli, produced as micromovies by Viehoever ('40). Adaptation to the environment and struggle for existence (perhaps with extermination of some external 'agencies'), as described by Darwin, cover many aspects of this fundamental law of life which, in its larger meaning, applies equally well to the economic axiom of supply and demand, to drug addiction, and to man's strife for freedom. Whether successful or not, the elimination tendency persists to the last, even during starvation, trauma, or disease.

The act of elimination, or circumstances incident to it, may actually constitute another influence, causing one or more additional (secondary) elimination responses, included in, or superimposed upon, the initial reaction. Moreover, two or more external influences may appear within short interval (*cf.* 'interference of excitation' in Verworn, '12, and 'conflicting stimuli' in Rashevsky, '51). The frequent occurrence in nature of such multiple events explains the intricacies and apparent contradictions of life phenomena.

According to the 'law of continuity' of Leibniz, natural occurrences proceed gradually; thus the elimination of either internal or environmental stress follows a smooth, logarithmic pathway. The influence predominates at first, until a critical point (climax) has been reached.

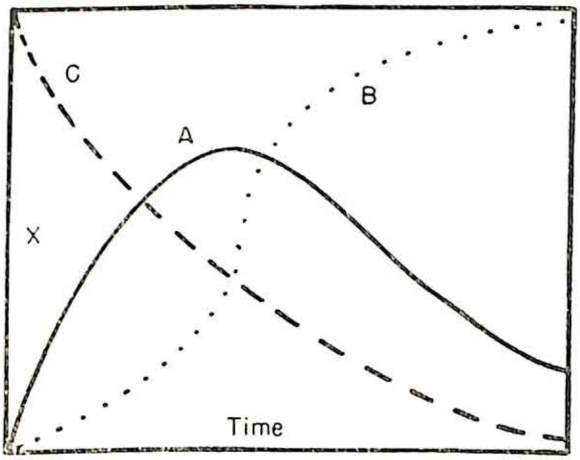

FIG. 1. LIFE'S BASIC TENDENCY IS THE ELIMINATION OF INTERNAL AND ENVIRONMENTAL INFLUENCES. Its graphic expression resembles an *aperiodically damped oscillatory motion* (A), of which a simple formula is $x = \alpha t e^{-\beta t}$. The integrated values of A are plotted in B, their reciprocals in C. Examples of observed curves are: A.—Elimination rate (or blood level) of ingested drugs; female fecundity by age groups. B.—Number of resistant bacterial strains after antibiotic therapy; relation between visual acuity and illumination. C.—Activity of an enzyme subjected to x-radiation; tissue retention of ingested substances.

Thereafter, the always longer second phase consists of a gradual return to the base line. A classical example is the response to excitation of striated muscle. This curve (fig. 1, A), known in mechanics as the *aperiodically damped oscillatory motion*, represents the speed of a pendulum, returning to its original position after a single swing, because of the extreme (theoretical) viscosity of the surrounding medium. Its simplest mathematical expression is

$$x = \alpha t e^{-\beta t}.$$

A fast reached, high climax must be followed by a relatively earlier decline (fig. 4, i). After a less abrupt ascent, middle-of-the-road values will be maintained for a longer time (fig. 4, ii). Rapidly growing tissue cultures die long before slower developing ones. A similar relationship is noted between the effort rate required for sprint (i) and for marathon (ii), or between the torrentuous sentimental outburst of teenagers and the dignified affective stream of mature individuals. A double alternation of this type has also been shown to exist between urban and extraurban increase rates of the population in Japan (Eto, '41). In many cities tuberculosis mortality exhibited early spiking (i), but it also fell faster, and in many places its figures are now below those (ii) of the surrounding rural areas (L'Eltore, '47).

Integration of above mathematical function gives a sigmoid, growth, logistic, cumulative, summation, or saturation tracing (fig. 1, B). Plotting the reciprocals of the integrated values results in a landing airplane curve (fig. 1, C), often encountered in physics, *e.g.*, expressing radioactive decay.

EXEMPLIFICATION

Patterns analogous to those in fig. 1, and their inverted (mirror) images (fig. 2) abound whenever graphic methods are applied to biometrics (McCarrison and Madhava, '32), especially in physiology, pharmacology, and demography. Quoted for illustration are tissue recovery rates after x-radiation (Kingery, '20), the increase in height of an evergreen tree (Szolnoki, '30), the incidence of decompression sickness as a function of exposure time or temperature (Nims, '51), the assimilation speed of albumin by the liver, determined by tracing radiosulphur tagged methionine in mice (Khesin, '54), and the tabulation by age groups of intellectual achievements of top grade individuals from various countries (Lehman, '54).

Being man made, economic changes disclose similar developmental cycles. The seasonal fluctuations of certain prices, of the labor market, and of foreign trade volume resemble damped motion curves (fig. 1, A), while saturation tracings (fig. 1, B) describe secular trends in commodity prices, in coal and iron productions, and trade volumes with specified areas (Wagemann, '28). Extrapolative procedures can be adapted, both to short range market problems, and to the long range depression wave forecast, but the frequent overlapping of secondary response cycles causes a regrettable loss in accuracy.

Calculus has also been employed to predict the outcome of biological events, such as speed of wound cicatrization (Lecomte du Noüy, '19), future world population figures (Pearl and Reed, '20), and the length of survival of patients suffering from chronic incurable diseases (Tivey, '54). Paired curves F (fig. 2) and B (fig. 1) may describe two aspects of one phenomenon, for instance, increase in height (F) and weight (B) of newborns, blood dissociation curves of carbon dioxide (F) and oxygen (B), and distensibility of veins (F) and arteries (B).

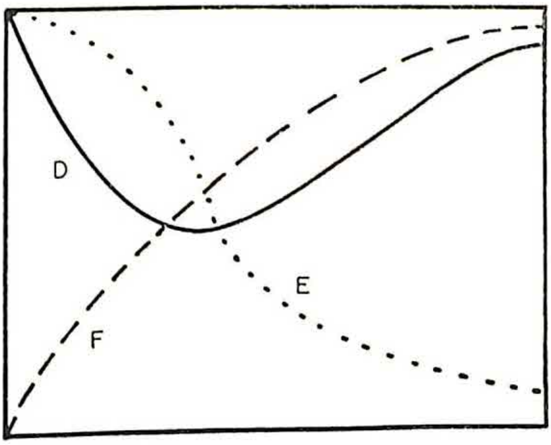

FIG. 2. INVERTED (MIRROR) IMAGES OF THE CURVES IN FIG. 1. Examples of observed tracings: D.—Death rate from accidental poisoning by age groups; respiratory quotient of excess metabolism caused by exercise. E.—Histamine effect on blood pressure in hypertensives; survival of protozoa exposed to high energy atomic particles. F.—Frequency response of sympathetic effectors; isometric muscle contraction.

These six curves (figs. 1 and 2) are calculated paraphrases of damped motion. By inference, the exponential patterns which describe biological occurrences represent transcriptions of the underlying elimination of external or internal influences. Rising air temperature will affect skin temperature, heat loss, and vaporization, but the elimination effect is achieved, as the rectal temperature remains fairly stable (DuBois, '39), and almost identical curves have been obtained in hibernating animals (Chao and Yeh, '50). In practice the identification of the original influence is not always possible, partly for the distortion of observed tracings by the inaccuracy of our measurements, and mainly because of obscuring secondary elimination responses. Moreover, beyond experimental confines, influences of constant strength may not be the rule.

THE ECOLOGICAL IMPETUS

However pernicious, the environmental stress may exert a stimulating effect, in the same way in which a war awakens often unexpected potentialities in a nation. The biologic strength of a community is higher at the end of an epidemic episode of an infectious illness, at which time the natural resistance of its population reaches a peak, after passive selection of the deceased and active immunization of the survivors. This remains statistically correct, even if in the case of scarlet fever some of those who survived may have acquired irreparable kidney disease. In certain chronic infections (syphilis, tuberculosis) major damage is done by the body's response to antigenic influences. Under the circumstances, virulence of a microörganism for a given host is proportional to the extent of reaction. A lessened response is a sign of resistance, while absence of response means immunity. The antigenic influence has been eliminated when the only reaction elicited by the former pathogen is that befitting a saprophyte, a presumption seemingly confirmed by the increasing proportion of tuberculin-negative reactors even among children heavily exposed to bacilliferous parents.

The tracings of either morbidity or mortality during an epidemic wave resemble curve A (fig. 1). For infections with protracted course, such as tuberculosis, secular figures (Gottstein, '48) may be required to demonstrate the actual pattern.

MORS JANUA VITAE

The ultimate in environmental stress is increased mortality of individuals up to and including the reproductive age. This challenge to survival is a prerequisite for the relative immortality of any species and, in a wider sense, for the perpetuation of life itself. The causality may seem heterodox by accepted standards, but only because many of the leading biologists have discarded the Heraclitic concepts, and have sided with Plato for most of the last two millenia. Statistical results do not necessarily apply to the individual, nor are they invalidated by small series. This is emphasized in the commonplace that what is good for the tribe could be evil for one of its members, and vice-versa. Conventional mechanics appear adequate at slow speeds, yet, in accordance with the thesis of Einstein ('13), relativistic adjustments become necessary as soon as momentum has been gathered. Obviously, static biology applies well to individual cases, or even to linear segments of a given exponential elimination response. Conversely, a dynamic approach is required for the understanding of a long term cyclic phenomenon in a community or species.[1]

War losses are sharp natality boosters, spreading this effect often to neutral territories, a fact reported in Switzerland (Jenny, '42). Psychological mechanisms may be involved, perhaps over endocrine channels. The existence of internal secretion responses to environmental stress has been proved by the pioneering research of Hans Selye. It should be more difficult to uncover the mechanism by which in wartime the usual surplus of male births is also increased, as if intended to prevent the prevalence of females in the general population.

The record breaking civilian and military casualties of World War II have been compensated with compound interest in a few years of armistice, as revealed by mid-century censuses. These include most of the nations with major losses, such as Germany and Great Britain. In some countries (Finland, Italy, The Netherlands, U. S. A.) the total population number never decreased throughout the war years. In the post-war period, overpopulation caused concern not only in Japan (Okasaki, '52), it fostered neo-Malthusianistic efforts all over the world.

The numeric increase of animal populations in their natural habitat follows the usual growth curve (fig. 1, B). The amount of food available, or space limitations cannot completely explain the final leveling off, as similar trends are observed in laboratory bred generations of *Drosophila melanogaster*, and in bacterial and tissue cultures. Perhaps a valid comparison can be made with the growth of trees (Szolnoki, '30), or with the weight increase in mammals, which shows analogous variations, even under pathologic circumstances.

Nonetheless, the levelling off may be postponed under certain conditions. At the height of the saturation tracing (maturity?), a numeric (biologic) balance, however transitory, is established between added (born) and deducted (dead) unities. Any survival challenging disturbance, such as breaking off a piece of tissue culture, will elicit increased mitotic activity (rejuvenescence?), which often overcompensates and reëstablishes saturation at a higher level than before. In the late 1930's, the population of France had reached maturity at about 40 millions and was on the verge of decline. The natality boom caused by the war losses of 1941-45 has reversed the situation: in 1954, at over 43 millions, saturation was still way ahead.

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[1] Among the many attempts to introduce relativistic symbols in biologic metaphysics is the reproduction of a *cuadridimensional* 'wheel of life' (slightly resembling the Brahmanic version of the wheel) by Jakob ('48), included with the statement that life is the fourth degree of the natural maturation of cosmic energy. A transformation of energy is also implied in the formula of Rulfo ('51), based on Rashevsky's interpretation of an application of the Hamiltonian principle by Lotka.

Far from limiting overpopulation, war is today a major factor in producing it. In the Middle Ages, mercenary forces constituted the bulk of every army. In those days low living standards, high infantile mortality, epidemics, floods, and famines were backing natality. The introduction of national armies in modern times has been followed by a sharper increase in world population. Should war be banished from the earth, a saturation point in its population could probably be reached in a not too distant future. The desirability of such a levelling off is a matter which, just like ethics, changes with time, place, and politics, and is therefore beyond the scope of this paper.

Theoretically, the indirect fertilizing value of deceased individuals varies with their age at death. High at birth, it falls off exponentially, and reaches insignificant levels shortly after the average end of the reproductive period. Since the initial peak is actually at conception, interrupted pregnancies should promote the natality increase. For practical purposes, it suffices to distinguish between infantile and adult mortality. The former causes an immediate increase in natality rates, while in the latter a *lag period* will be interposed, to replenish the ranks of the reproductive age group. Hunting regulations, aimed to preserve wild life, follow identical reasonings.

Fulminating disasters of geologic or cosmic origin could wipe out the life on an island, on a continent, perhaps on the entire planet. Short of eradication, catastrophic death rates, such as those obtained during certain insecticidal and germicidal procedures, result only in prolongation of the lag period, with ultimate restoration. Strains resistant to D. D. T., or to antibiotics, have emerged as a proof of life's consistent tendency to eliminate any disturbing influence. In man, on a smaller scale, a similar instance was the survival (and revival ?) of the American Indians. So far, no war has come anywhere close to causing catastrophic death rates of world-wide magnitude, but improved thermonuclear devices might lead to such an accomplishment in the future. It is safe to assume that even then the human race will emerge from the cinders, although the lag period could be lengthy.

Civilization has reduced infantile death rates in many countries, leading to a decrease in natality, quite evident in the interval between wars, even if the interpretations vary from one author to another. The gruesome ritual sacrifice of children and virgins by primitive peoples, intended to foster fertility, may have an empirical rather than a metaphysical rationale. This observation should not be misinterpreted as condoning or advocating death by war or in any other way. The notions of good and bad are alien to nature, they had to be created by man. Newborn bear cubs are sometimes devoured by their father, and this occurrence is not uncommon among other animals. Whether civilized or savage, kin or no kin, a big fish will prey upon little fishes. And yet, the naturalists who first reported these obvious facts have been accused of the intention to recommend similar procedures for human beings. Man is part of the natural world and, even if the evidence is unpalatable or may mean a painful readjustment of his beliefs, he must go on searching for knowledge, for without his curiosity he would be nothing (Adrian, '54).

THE CHANGING TIDE OF DEMOGRAPHIC DEVELOPMENT

During the life cycle of a nation, its population figures follow the ascending pathway of a sigmoid curve, continued with the latter's inverted image (fig. 3). The growth begins with slowly rising numbers: this is the above mentioned *lag*, found also in bacterial, tissue, and protozoa cultures. The change to the second period, a steep slope of exponential multiplication, often coincides with, or perhaps causes, historical changes such as the American Revolution. (The biological background of military and political events is seldom recognized, even in retrospect.) At maturity, with a stationary population, the tracing enters a horizontal, saturation phase. Yet, there is no true stationary phenomenon in life. The threshold is due to prolongation of the individual life span, which maintains an apparent stability of the total population number, despite a dwindling natality. Death is bound to come, and when the accumulated surplus of old age groups becomes part of the mortality statistics, there is a sharp falling off, the stage of decay.

The last portion of the curve (broken segment of the population tracing in fig. 3) straggles toward a virtual parallel with the base line, as seen in the vitality decay of *Uroleptus mobilis* in isolation cultures

(Calkins, '33). In the case of a nation, a slow end is seldom, if ever, seen. As in the fall of the Roman Empire, long before the theoretical finish, demographically younger population groups take over, biologically or otherwise. Each of the newborn nations continues its own pathway on a similar cycle, but the start is not at the base line; it is at the point to which the ethnological mixture has set it back on the biological clock (as usual, most important for common mortals is the relative, not the absolute time).

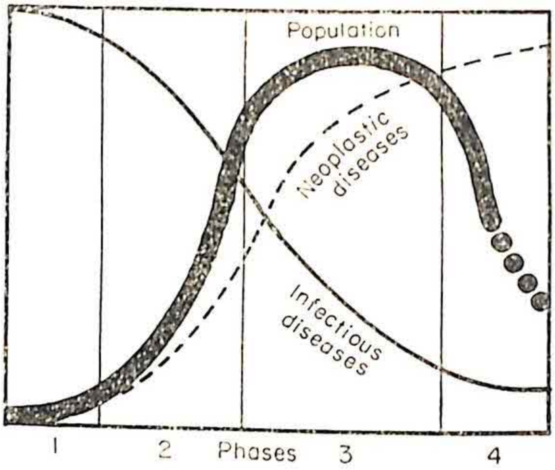

FIG. 3. THEORETICAL POPULATION CURVE DURING THE LIFE CYCLE OF A NATION. The four phases can be duplicated in the laboratory with bacterial, protozoa, or tissue cultures: lag, exponential multiplication, saturation, and decay. The end is often abrupt, as the aging population is incorporated by its neighbors. The resulting newborn nation(s) will continue a similar development from a starting point (rejuvenation or reversal of the biologic clock) determined by the degree of racial intermingling. With advancing biologic time, there is a decrease of infectious diseases (as well as of natality, and of general and infantile mortality), and an increase of neoplasms (and also of other degenerative diseases, of the individual size, and of longevity). The maturation point of population growth may be reached earlier if the death rate declines ahead of time (civilization), or it may be delayed by added mortality (war ?) with consequent increase in natality and infectious diseases, and decrease of neoplasms.

A composite curve, resembling the population tracing in fig. 3, is often encountered in nature, *e. g.*, the pressor response of the heart rate. The excitation state during coitus evolves in a similar fashion (Van de Velde, '26), the acme (orgasm) corresponding to the saturation phase. In the male, regardless of duration of the lag period, the summation time preceding the acme is shorter (steep ascent), consequently the defervescence stage ends faster than in the female (Rohleder, '11). Analogous differences in speed and reaction time exist between the adrenergic and the cholinergic responses of the neuro-vegetative system. This serves to emphasize that the pendular aspects of the various dualistic systems in nature, such as the concept of Yin and Yang in ancient Chinese medical lore, reveal an asymmetry which can be explained by the inherent features of the respective reaction curves. Fewer females are born, but they live longer (*cf.* the concept of *Geschlechtsströme* in Rauber, '00), and prevail numerically in aging populations. The surplus of males in younger communities is preserved, despite war losses (in part by migration), as shown already by Graunt (1676). These and other dissimilar findings in the two sexes, somatic and psychologic, in health and disease, can be traced back to the masculine and feminine types of response to disturbing influences (fig. 4). They are substantialized in the different numerical values given to α (magnitude of response) and β (steepness of slope) in the male and female curves calculated from the basic formula.

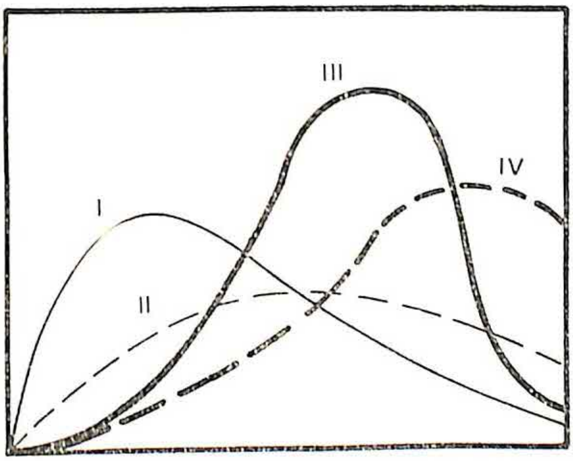

FIG. 4. MASCULINE AND FEMININE TRACINGS. The numeric values, replacing α (height) and β (slope) in the basic formula, determine the shape of the curve. The two extremes, in the simple form (i, ii), or transposed into composite tracings (iii, iv), represent contrasting entities, *e.g.*, acute (i, iii) and chronic (ii, iv) diseases, animals (i, iii) and vegetables (ii, iv), even abstract notions, such as functional (i, iii) and organic (ii, iv). It seems that also symbolically life is built on the dualistic system (pendular but asymmetric) of the male (i, iii) and female (ii, iv) principles.

CONSEQUENCES OF THE DEMOGRAPHIC EVOLUTION

Among the numerically important causes of natural death are infectious and neoplastic diseases. Their respective frequency varies during the life cycle of a nation (fig. 3). The observed decline of infectious pathogenicity is not entirely the result of public health measures. In the past, pandemics such as leprosy, and repeated epidemic waves of typhus, cholera, and plague have receded spontaneously. This decline is difficult to evaluate when considering recent figures, because of the intensive sanitary activity, which in civilized nations has succeeded to reduce, or practically to eradicate, certain diseases, such as the once so dreaded Yellow Fever. Nevertheless, some logical deductions can still be made.

In the case of diphtheria, not too many authors believe that the serum was the cause of the last half century's drop in death rates; furthermore, vaccination with anatoxine did not prevent the outbreak of recent epidemics (Morton, '41; Merkel, '51). The opinion has been expressed that incomplete vaccination accounts for the outbreaks: if this can be accepted, what is left to account for the overall decline of diphtheric morbidity and mortality? In Finland treatment with sulphonamides and penicillin has had little or no effect on the mortality rate of pneumonia, which had started to fall much earlier (Peltola, '54). Likewise, tuberculosis figures began to come down many decades, in some places even centuries, before the introduction of isolation measures (today still incomplete). In fact, in all three instances the decrease slowed down as the curve approached the base line. This is inherent to its exponential function and must not be misinterpreted as the contraselective result of hygienic and medical techniques.

Nicolle ('30) has pointed out that epidemic outbreaks can be explained by a sudden increase in microbial virulence, due to spontaneous mutations; conversely, the virulence cannot decrease in the same way, because it is unlikely for identical mutations to appear simultaneously in astronomic numbers of bacteria; the lowering of infectious morbidity and mortality can be explained by the natural selection of those with either innate or acquired resistance. One should again realize that values may be reversed at the individual level: at times, antidiphtheric serum effects startling recoveries in desperate cases; the lifesaving usefulness of penicillin needs no reminder; and newborns must be separated from mother who have active pulmonary tuberculosis (fig. 5).

The increasing incidence of neoplastic diseases (fig. 3) is only in part an expression of changing age distribution with preponderance of the older groups. Other degenerative conditions (baldness, tooth decay, refraction defects) and certain nosologic groups (metabolic, endocrine, allergic) are also on the increase, which suggests the possibility of biologic deterioration of the germinative cells. Old infusoria cultures reveal how repeated mitoses in a cell series result in monster formation from incomplete division, and in other degenerative changes, both in nucleus and protoplasma.

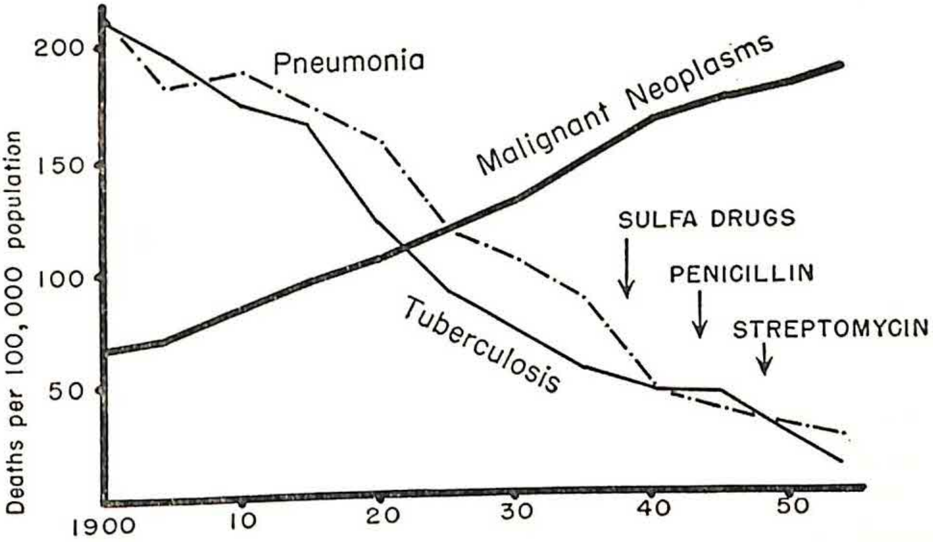

FIG. 5. INFECTIONS AND NEOPLASTIC MORTALITY IN NEW YORK STATE. The tracings have been drawn from five-year interval data supplied courteously by the Biostatistical Office of the Health Department of the State of New York. The advent of three 'wonder-drugs' is marked with arrows. For individual cases, these three drugs have delayed the fatal issue (lifesaving is a poetical misnomer with a prosaically provisional connotation: we must all die some day) more often than all the other antibiotics combined. Still, when viewed through the widened perspective of large figures, a comparison is permissible with La Fontaine's fable of the horsefly which helped to pull the carriage by waving its wings while hanging on to the horse's neck.

Infectious diseases prevail among younger age groups, and as such are a threat to survival, which is of help in maintaining high natality figures, but it also elicits a response tending to eliminate these ailments. Neoplastic diseases affect mostly older people, and therefore do not challenge the survival of a population; on the contrary, their increase coincides with a prolonged life span. Actually, the population's fertility should benefit (indirectly) from fatal malignancies appearing before the end of the reproductive period, but this influence is small, because of the relative rarity of tumors in younger individuals with consequently minimal total loss in reproductive man-years. On the other hand, when in certain infectious diseases, during the last stages of their epidemiologic cycle, the resistance of the younger generations causes a shift toward older groups, this results in a commensurate decrease in the effect of these particular ailments on natality.

Diagnostic incongruities in the past, and the prolonged life span of the present were assumed to account for, but cannot fully explain, the mounting neoplastic morbidity. In Austria, a physician-coroner's inquest is compulsory for every death certificate, adding considerably to the accuracy of mortality statistics: as their death rate from malignant blastomata has remained fairly stable for the last 25 years, a concomitantly sharp rise in the total neoplastic mortality was interpreted as a proof that cancer does increase independently of age distribution (Puntigam, '47). This is also borne out by age-adjusted cancer death rates for the United States: 80 per 100,000 in 1900, 97 in 1910, 105 in 1920, 113 in 1930, and 120 in 1940 (Moriyama and Gover, '48). The figures are still rising; they were close to 125 in 1950.

Actually, within a nation, various geographical subdivisions, cities, even minority groups folllow their own life cycles, similar to that of the entire nation, but not necessarily coincidental. There are proportionally more infectious and less neoplastic diseases in the rural population than among city dwellers. A recent study by the Bureau of Ethnic Research of the University of Arizona revealed that Arizona Indians are comparatively (1) more liable to die of infectious diseases, and (2) less susceptible to 'constitutional' ailments (neoplastic, allergic, metabolic, endocrine, circulatory), while (3) their elevated natality causes a steady 1–2% annual increase in their total number, despite (or shall we say, because) of a high general, and especially infantile, mortality.

A sizable source of etiological speculation was the undeniable fact that in mental hospitals the incidence of tuberculosis appears higher, the life span shorter, and the proportion of neoplasms lower than in the communities of origin of the respective institutional populations (Grigg, '55). Statistical comparison shows that the overall rates in mental patients trail the national average by 10-20 years, as if the psychotic condition could reverse the biologic clock, a supposition enhanced by the alleged high potential fertility of mental patients. According to Lamont ('48), in South African mental institutions the 'Cape Coloureds' (a heterogenous ethnic group, mainly of Hottentot and Bantu origin, with both Asiatic and European inflexions) die more often of tuberculosis than patients of pure European descent; even when tuberculosis is excluded, the white chronic schizophrenic tends to live longer. Racial differences in the degree of neoplastic malignancy were also revealed by the calculations of Greenwood ('26), based on Janet Lane-Claypon's statistical material assembled in the general population.

Whatever the interpretations offered, it is undoubtedly true that *there are no basic, standard, average, or otherwise stable morbidity or mortality rates of either infectious or degenerative* (including neoplastic) *diseases.* The continuous changes observed are the consequence of advancing biologic age, while rate differences between two or more racial or geographic groups are in fact phase differences.

Life's ultimate goal is complete elimination of all disturbing influences, particularly of the environmental stress, yet if and when achieved, it leads to the death of the respective biologic group. Disappearance of the gigantic Cretaceous dinosaurs, the most powerful and elaborate creatures of their time, was probably due to failing reproduction, but minuscule lizards are still available to impersonate their bygone kinship in the magnifying perspective of movie cameras. When a group advances in biologic age, its individuals increase in size, but decrease in fertility, *viz.*, the difference between Scandinavians and Mediterraneans. Similar discrepancies may be noted between urban and rural areas and, moreover, since purity of race or clan can substitute for its age, between the inbred patriciate and the intermixing plebe. Large mortality rates of 'traumatic' origin can maintain a short stature and high natality over long periods of time (Jews, Chinese). Maybe civilization, by raising the life standard and lowering the death rate, accelerates the biological aging process. Suits of armor in museums are too small for the average man of today. Berths on sleeping cars have been lengthened by half a foot in the past eighty years. Skeletons of the extinct Cro-Magnon race, the most civilized in prehistoric times, are often from oversized individuals. It might be of interest to determine proportionally the procreative contribution of the tall, 'career-girl' type of woman.

at all. The debased leprosy, and the more recent withering of the tuberculous pandemy are also arguments in favor of Sydenham's allegoric representation of infectious diseases as falling empires. The tumors follow the opposite path, and study of their natural history at different times and places should reveal a progressive increase in the degree of malignancy (with shift toward younger age groups?) as well as a proportional reduction of the five-year survival rate in untreated cases.

Lecomte du Noüy ('36) discussed 'biological time' as related to the aging process of the individual (wounds heal faster in children), and mentioned briefly a *temps de l'espèce*. The idea of pathologic changes related to advancing time was applied by Grote ('48) to the phasic phenomena, of which there are many examples in medicine. Actually, the concept must be extended until today's prevailing postulate of the fixity of diseases shall appear as absurd as the fixity of species. Comparison at face value of treatment statistics of either infectious or neoplastic diseases is a fallacy, unless due consideration is given to the biologic age of the respective demographic groups. This is one of the main reasons why results of animal experimentation do not have to apply in man. Further generalization will emphasize the continuous change in relation to time as an essential feature of life phenomena. Even the converging, diverging, and interfering cycles which constitute the biocosmos could be imagined in the form of a gigantic maze, expanding spherically as it floats with poise along a damped pathway toward infinity.

ADDENDUM

Thomas Huxley expressed the warning that it is the customary fate of new truths to start out as heresies and to end up as superstitions. In the beginning, the theoretical basis of this paper may be opposed, mainly by those who employ wishful thinking in their search for finality in nature. At some later date, the fundamental law of life will probably be evaluated from the viewpoint of obtaining "desirable" changes, a task both delicate and unrewarding. Considering our microcosmic limitations, the ultimate in wisdom calls perhaps for acceptance of the macrocosm as it is, trying to change less, and to understand more of the *Dark Philosopher*'s harmonious, universal reason, the *logos*. And maybe the fire which he regarded as the world's basic element is actually the symbol of life, ever changing in the constantly flowing nature of things, for undoubtedly πάντα ῥεῖ.

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THE ABO BLOOD GROUPS AND THE SEX RATIO

BY BERNICE H. COHEN * AND BENTLEY GLASS

The Johns Hopkins University, Baltimore

FROM the Biblical peoples who sought by divine aid to beget sons rather than daughters and from the primitive societies which have tried to control their populations by female infanticide, to those 20th century biologists who have been investigating the etiology of the proportions of males to females, interest in the sex ratio has been universal. In the course of time, comprehension has proceeded from the spiritual to the practical realm and back to the no less mysterious laws of probability—that there is slightly better than a 50/50 chance that the Y-bearing spermatozoon will outdistance the X-bearing one.

It is well established that less than fifty girls are born for every fifty boys (Ciocco, '38; Bernstein, '51, '52, '53; Jalavisto, '52a, b; Lienhart, '52; *et al.*). Actual estimates of the excess of males among live births vary for different populations and conditions: from low estimates of 103 and 104 : 100 for Salvador and Japan respectively to a high of 113-140 : 100 in Greece and Korea, 1921-1929 inclusive (Russell, '36). In the U. S. Birth Registration Area ± 105-106 : 100 was reported for 1917-1934 (Ciocco, '38); and "in 19164 cases collected from Finnish and Swedish published family history records," a fairly normal male birth rate, 107 : 100, for the nobility and "a considerably higher sex ratio" 122 : 100, for middle class families (Jalavisto, '52b). Moreover, the primary sex ratio at conception [males/(males + females) times 100] is not necessarily the same as the sex ratio at birth (Ciocco, '38; Tietze, '48; Bernstein, '51, '54; Dahlberg, '51). More stillbirths and more spontaneous abortions are thought to occur among males than among females, particularly at certain stages of gestation (McKeown and Lowe, '51; Jalavisto, '52a), although the study of Tietze ('48) calls this conclusion in question. He obtained a sex ratio of 107.9 : 100 in a study of 5787 embryos and fetuses of the 3rd to 7th months of pregnancy.

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* Public Health Service Research Fellow of the National Heart Institute.

Within recent years there have been many reports in regard to the influence, or lack of influence, of numerous factors on the sex ratio:

Birth order	(Russell, '36; Ciocco, '38; Lawrence, '41; Martin, '43; MacMahon and Pugh, '53)
Family size	(Russell, '36; Lawrence, '41; Thomas, '51; Jalavisto, '52b)
Sex of first-born	(Lancaster, '50)
Maternal age	(Martin, '43; Lowe and McKeown, '50; Jalavisto, '52a, b; Takahashi, '52, 54a, b; Bernstein, '53; Novitski, '53; Myers, '54)
Paternal age	(Jalavisto, '56b; Bernstein, '53; Novitski, '53)
Relative ages of father and mother	(Ciocco, '38; Lawrence, '41; Bernstein, '53)
Ancestral longevity	(Lawrence, '41; Jalavisto, '52b)
Action of genes through the endocrine system	(Bernstein, '51)
Physique and temperament	(Heath, '54)
Physiological and biochemical factors (mice)	(Weir, '53)
Artificial insemination	(Jalavisto, '52b)
Frequency of intercourse	(Jalavisto, '52b)
Time of conception during menstrual cycle	(Lawrence, '41; Jalavisto, '52b)
Seasonal and monthly variation	(Russell, '36; Ciocco, '38; Takahashi, '52)
Geographical and climatic conditions	(Ciocco, '38)
Illegitimacy	(Ciocco, '38)
Race and color	(Ciocco, '38)
Parental occupation	(Bernstein, '51, '54)
Social status and socio-economic conditions	(Russell, '36; Ciocco, '38; Lawrence, '41; Martin, '43; Bernstein, '53, '54)
Urban-rural and other differences	(Russell, '36; Ciocco, '38)
War and post-war periods	(Russell, '36; Myers, '49; MacMahon and Pugh, '53, '54)

One of the most provocative reports of any was published in 1951 by Sanghvi. It indicated a certain relation between the ABO blood-group constitution of mothers and offspring and the sex ratio at birth but left the possible cause of such blood-group/sex-ratio correlation

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obscure. Maternal isoimmunization is here ruled out because the reported differences occurred in combinations where mother and infant were of identical blood groups, such as A/A; and no data have ever suggested any linkage between the autosomal ABO blood-group factors and the X–Y chromosomes (see Sanghvi, '51; Johnstone, '54). Yet the marked similarity between Sanghvi's two independent samples of widely different populations, taken respectively in New York and Bombay, is very striking. These results, together with the suggestive findings of Waterhouse and Hogben ('47) concerning the differential fertility of reciprocal matings, particularly A × O compared with O × A, and of Allan ('52) concerning fertility differences in mothers and fathers of different blood groups, have led us to undertake a further investigation of those problems on some Baltimore population samples. Meanwhile, Johnstone ('54) has published a study, similar to that of Sanghvi, upon a West London population. In the present paper, which will be concerned primarily with the relation of the sex ratio to parental ABO blood groups, the Baltimore data will be presented in detail, will then be compared with the data reported by Sanghvi and by Johnstone, and will finally be combined with the other series to form a pooled sample wherein statistical variability is lessened. Further studies on the differential fertility rates of various mating types, and a comparison of the Baltimore data with the findings of Waterhouse and Hogben and of Allan, will be presented elsewhere.

SOURCE OF MATERIAL

The original data were taken from the records of the Baltimore Rh Typing Laboratory for the years 1947 through 1953, inclusive. Two separate series were tabulated. The first (Balto. Rh) consists of Rh-negative non-sensitized women married to Rh-positive men. Every history in the "non-sensitized" files was utilized if it specified the ABO blood group of the mother and the blood group and sex of one or more children, provided that there was no contradiction or inexplicable discrepancy in the record (such as AB mother and O offspring, or discrepancy between replicate blood typings). The father's blood group was tabulated whenever it was available. Sensitized mothers were excluded because maternal isoimmunization tends to cause a higher rate of stillbirths and neonatal deaths. In view of the possibility, already mentioned, that there may be a sex differential in pregnancy wastage, and because this might apply to losses due to Rh incompatibility as well as to other causes, any influence of the ABO blood groups on the sex ratio of the offspring might be distorted or masked by Rh hemolytic disease.

The second series (Balto. Pat.) consists of cases of mothers and offspring typed in connection with disputed paternity suits at law. These were of mixed Rh types, and thus serve as a control series for checking the randomness as respects the ABO groups of the larger Rh-negative non-sensitized series. In this series no male parents were included.

METHODS

In both Baltimore series (Rh and Pat.) there were families in which the blood group of the mother and the sex and blood groups of more than one offspring were available. These families were consequently tabulated in two different ways: (1) as *multiple determinations per family* (table 3), each offspring being used in a separate parent-offspring combination; and (2) as a *single determination per family* (table 3), in which case only the oldest child of known sex and blood group (not necessarily the oldest child in the family) was used to represent the family. Selection of the oldest child was made because of the greater reliability for blood typing of venous blood samples than of cord blood from newborn infants; and also in order to eliminate possible errors due to postponed development of the blood type, as reported to occur in the case of the group A antigen.

The two Baltimore samples (Rh and Pat.) are tabulated separately, and so are the data from single and multiple determinations per family within each series. Inasmuch as the comparison of these series revealed no significant statistical differences between the Rh and the Paternity series, either according to single ($\chi_{14}^2 = 13.81$; $.50 > P > .30$) or multiple ($\chi_{14}^2 = 17.28$; $.30 > P > .20$) determinations per family, the Rh and Paternity series have been combined in a Pooled Single Series and a Pooled Multiple Series.

In addition to the large pooled samples (Balto. Pooled Mult., B–S–J), each series is presented independently in order to demonstrate that the deviations are not a function of the method of sampling. From inspection of the separate samples, it is apparent that the results are not influenced by an ABO–Rh interaction, as has been suggested for isoimmunization (Levine, ’43; Fisher, ’44; Race and Sanger, ’50; Mollison, Mourant, and Race, '52; Heistö, '55). In the Balto. Pat. series and the Johnstone series, both of which are composed of mixed Rh types, similar deviations appear as in the Balto. Rh series composed of Rh-negative non-sensitized mothers and Rh-positive fathers exclusively. It is likewise apparent that the results are not influenced by any selective action against infants of certain ABO blood groups in the early years of life as opposed to a prenatal effect, an hypothesis that might be suggested by the autopsy studies of Struthers ('51). For, while the Baltimore samples included offspring irrespective of age (including about 50% of cord bloods), three other samples included newborn infants only. Both Sanghvi series—Bombay and New York—used cord bloods, and Johnstone in his West London series utilized "tube techniques on all mothers delivered in the maternity department of West Middlesex Hospital . . . [throughout the year 1950]." Not only do all the samples show the same major trends independently but cell by cell they are not significantly different from one another (see the χ^2 values for the differences between series making up pooled samples, pp 23, 28, 30, 31).

For the sake of simplicity in tabulation and reference, the sex ratio is indicated in the form of the percentage of males among all tabulated offspring, rather than as the number of males per 100 females. In all the following tables, wherever matings are designated, the blood group of the female parent stands first, and the male follows. Although this violates what has become a convention in referring to human matings, it accords with the practice of geneticists who work with other species of plants or animals, and there seems to be no good reason for those who are discussing human genetics to deviate from common practice and thereby introduce inconvenience if not confusion.

For the statistical analysis of proportions, the chi square test was selected as being both the most reliable and the most practical (Cochran, '52; Fisher and Yates, '53). We have utilized a somewhat different method of analysis from that of Sanghvi or Johnstone. Sanghvi compared A/A mother-offspring blood group combinations with O/O, and also with B/B, as being combinations "large enough for further observation." It appears better to base the analysis upon the entire sample, and then, by partitioning χ^2, to determine what combinations contribute most significantly to the variance. We will also compare (1) the sex ratios in the total offspring of parents of each of the four blood groups; (2) the sex ratios among total O, A, B, and AB offspring, respectively, disregarding the parental blood group; and (3) the sex ratios in the complete series of parent-offspring combinations of matched blood groups, *viz.*, O/O, A/A, B/B, and AB/AB. The third of these comparisons would be that in which the least extraneous interaction, such as that producible by isoimmunization, would be expected to occur.

SUBJECTS

When multiple ascertainment was used, there were 3577 mother-offspring combinations in the Rh series and 961 in the Paternity series. The two Baltimore series combined thus virtually equal in sample size the three combined series of Sanghvi (Bombay; New York) and Johnstone (London), previously reported. In the Baltimore Rh series 3037 individual families were represented; in the Paternity series, 900 mothers. From the Rh series alone came the 2827 father-offspring combinations (table 4) and the 2295 mating combinations (table 5).

Both Rh and Paternity samples comprised mixed racial groups. Only White and Negro classifications were available from the records; the few Mongoloids present were probably included with the Whites. The Rh series was 86.8% White, whereas the Paternity series contained only 25.0% of Whites. When pooled, the two series were approximately 74% White. Because the data of the Baltimore Rh Laboratory are used primarily for obstetrical purposes, more detailed information is collected for mothers than for fathers. Both age and race were indicated for 2941 mothers of the Rh series; race but no age was given for 767 mothers of the Paternity series.

The blood type distribution by race (table 1) shows, as would be expected, a smaller proportion of A and a larger proportion of B among Negro mothers than among White mothers. The distribution appears to be a representative sample of both White and Negro populations in eastern United States, at least in urban areas of the Middle Atlantic States. The frequencies for the Negro population agree very well with those reported by Glass and Li ('53) for a Baltimore Paternity series, although the present data given in table 1 are based on the Rh series alone. The present frequencies for the Baltimore Whites likewise agree closely with those used by Glass and Li, which were derived from New York City (Tiber) and North Carolina (Snyder) (see references in Glass and Li, '52).

From table 2 it may be observed that a similar proportion of each blood group occurs in each age group. The percentage of each blood group within an age group falls within the confidence limits for the total individuals in that age group, with the exception of two cells containing very small numbers. There is a relatively small proportion of AB mothers in the 20-24 year-old age group, but this is not significantly different from the largest proportion of 20-24 year-old mothers, the B mothers [t value = 0.699; not significant]. The other exception is to be found in the relatively large proportion of AB mothers over 35 years of age. Again, this is not significantly different from the group of mothers, of group O, yielding the smallest proportion past 35 years of age. Hence any possible bias due to the influence of maternal age upon the sex ratio is excluded.

TABLE 1

Blood Group Distribution of White and Negro Mothers of Baltimore Rh Series

	O			A			B			AB			TOTAL
	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.
	No.	%	%	No.	%	%	No.	%	%	No.	%	%	
White	1109	43.5	45.2	1048	41.1	39.5	296	11.7	11.2	99	3.9	4.2	2552
Negro	185	47.6	47.6	108	27.8	28.3	83	21.3	20.0	13	3.3	4.1	389
Total	1294			1156			379			112			2941

The frequencies of ABO blood types used by Glass and Li ('53) and quoted above were derived from New York City and North Carolina Whites and Baltimore Paternity Series Negroes, and hence are different samples from the Baltimore Rh group of this study.

TABLE 2

Age Distribution of Mothers (Rh Series) According to Blood Group

	O		A		B		AB		TOTAL	
AGE	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
<20	123	9.5	114	10.8	37	9.8	12	10.7	286	9.7 ± 1.8
20–24	379	29.3	314	27.2	114	30.1	26	23.6	833	28.3 ± 1.6
25–29	431	33.4	369	31.9	118	31.1	36	32.1	954	32.4 ± 1.5
30–34	258	20.0	246	21.3	69	18.2	23	20.5	596	20.3 ± 1.7
35 +	103	8.0	113	9.8	41	10.8	15	13.4	272	9.2 ± 1.8
Total	1294		1156		379		112		2941	

RESULTS

The data and the statistical analyses given in tables 3 through 6 are largely self-explanatory. Only a few pertinent facts need be brought out.

TABLE 3a

Sex Ratio and Mother-Offspring Blood Group Combinations

OFFSPRING		MOTHERS									
		O		A		B		AB		TOTAL	
		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
O	Balto. Pooled Single	**1179**	**50.8**	456	50.7	175	50.3			1810	50.7
	Balto. Rh Multiple	**1027**	**50.6**	432	52.1	148	51.4			1607	51.1
	Balto. Pat. Multiple	**326**	**53.4**	94	46.8	49	49.0			469	51.6
	Balto. Pooled Multiple	**1353**	**51.3**	526	51.1	197	50.8			2076	51.2
	Sanghvi Bombay	**261**	**60.5**	88	52.3	97	54.6			446	57.6
	Sanghvi N. Y.	**272**	**56.3**	99	45.5	42	50.0			413	53.3
	Johnstone	**758**	**50.9**	271	53.5	70	58.6			1097	52.1
	Pooled Balto.–Sanghvi–John.	**2342**	**52.6**	984	51.3	406	53.0			4033	52.3
A	Balto. Pooled Single	423	51.5	**857**	**47.7**	68	52.9	75	49.3	1423	49.2
	Balto. Rh Multiple	407	51.4	**828**	**48.3**	57	57.9	64	51.6	1356	49.8
	Balto Pat. Multiple	82	54.9	**176**	**42.6**	20	40.0	21	47.6	299	46.2
	Balto. Pooled Multiple	489	51.9	**1004**	**47.3**	77	53.3	85	50.6	1655	49.1
	Sanghvi Bombay	105	47.6	**217**	**49.8**	35	57.1	32	50.0	389	49.9
	Sanghvi N. Y.	106	51.9	**186**	**45.7**	12	50.0	12	75.0	316	49.1
	Johnstone	275	54.2	**691**	**49.9**	20	55.0	35	60.0	1021	51.5
	Pooled B–S–J	975	52.1	**2098**	**48.3**	144	54.2	164	54.3	3381	49.9
B	Balto. Pooled Single	196	54.1	74	39.2	**232**	**56.9**	60	61.7	562	54.1
	Balto. Rh Multiple	169	53.3	69	44.9	**178**	**59.6**	60	53.3	476	54.4
	Balto. Pat. Multiple	52	50.0	13	15.4	**87**	**52.9**	14	78.6	166	51.2
	Balto. Pooled Multiple	221	52.5	82	40.2	**265**	**57.4**	74	58.1	642	53.6
	Sanghvi Bombay	78	57.7	47	48.9	**215**	**57.7**	43	58.1	383	56.7
	Sanghvi N. Y.	44	47.7	11	63.6	**44**	**65.9**	11	63.6	110	58.2
	Johnstone	72	54.2	47	61.7	**81**	**54.3**	30	43.3	230	54.4
	Pooled B–S–J	415	53.3	187	49.2	**605**	**57.7**	158	55.7	1365	54.9
AB	Balto. Pooled Single			67	58.2	53	45.3	**22**	**59.1**	142	53.5
	Balto. Rh Multiple			59	57.6	59	44.1	**20**	**55.0**	138	51.5
	Balto. Pat. Multiple			17	52.9	7	71.4	**3**	**66.7**	27	59.3
	Balto Pooled Multiple			76	56.6	66	47.0	**23**	**56.5**	165	52.7
	Sanghvi Bombay			41	46.3	46	54.3	**25**	**56.0**	112	51.8
	Sanghvi N. Y.			11	81.8	8	50.0	**6**	**66.7**	25	68.0
	Johnstone			34	47.1	36	50.0	**11**	**45.5**	81	48.1
	Pooled B–S–J			162	53.7	156	50.0	**65**	**55.4**	383	52.5
TOTAL	Balto. Pooled Single	1798	51.3	1454	48.7	528	53.0	157	55.4	3937	50.8
	Balto. Rh Multiple	1603	51.1	1388	49.7	442	54.5	144	52.8	3577	51.1
	Balto. Pat. Multiple	460	53.3	300	43.3	163	50.9	38	60.5	961	50.1
	Balto. Pooled Multiple	2063	51.6	1688	48.6	605	53.6	182	54.4	4538	50.8
	Sanghvi Bombay	444	57.0	393	49.9	393	56.5	100	55.0	1330	54.6
	Sanghvi N. Y.	422	54.3	307	47.6	106	56.6	29	69.0	864	52.8
	Johnstone	1103	51.9	1043	51.3	207	55.1	76	51.3	2429	51.9
	Pooled B–S–J	4032	52.6	3431	49.5	1311	54.9	388	55.2	9162	51.8

Mother-Offspring Combinations. In table 3 only the pooled totals of the Rh and Paternity series involving single ascertainment per family have been entered, inasmuch as the two series did not exhibit any significant differences. Although there are also no significant differences between them, the separate Rh and Paternity series involving multiple ascertainment per family are given, in order to permit the comparison of effects on the sex ratio in the two series with different proportions of Whites and Negroes, and with selected vs. unselected Rh types. Inasmuch as the Pooled Single and Pooled Multiple series are not dissimilar ($\chi_{14}^2 = 0.67$; $P > .99$), the latter has consistently been used for the comparisons with the series compiled by Sanghvi and Johnstone. Furthermore, the statistical analysis having shown that that Baltimore series does not differ significantly from the pooled New York and Bombay series of Sanghvi or the London series of Johnstone, these have all been combined in one Pooled B–S–J Sample ($\chi_{28}^2 = 25.44$; $.70 > P > .50$).

In both Baltimore samples, Rh and Paternity, by either multiple or single ascertainment per family, and in agreement with Sanghvi's data, the total offspring of A mothers and the A offspring of all mothers exhibit a relatively low sex ratio, *i. e.*, the proportion of males in each case falls below 50%. Although in Johnstone's series the corresponding values exceed 50%, they are nevertheless below the total sex ratio for his series (51.9) and for the pooled Baltimore-Sanghvi-Johnstone data (51.8). In the pooled data there is a highly significant reduction in the sex ratio for the total offspring of A mothers (P almost 0.001) in comparison to B, AB, and O mothers; and there is a significantly low sex ratio among the A offspring of all mothers, in comparison to the B, AB, and O offspring of all mothers ($P < 0.01$). [An inconsistency may be seen in the fact that, whereas the mother-offspring tabulation yielded a significantly low sex ratio for the total A offspring, the father-offspring tabulation (table 4), based on 1085 of the 1356 A offspring in the Rh multiple ascertainment series, did not.] Of the independent samples, however, only the pooled Sanghvi series reaches levels of statistical significance for these differences.

As might be expected from the low sex ratio of all offspring of A mothers and the low sex ratio of the A offspring of all mothers, the A/A mother-offspring combinations in particular show a consistently low sex ratio in comparison with the other matched mother-offspring combinations (B/B, AB/AB, and O/O); and this is true not only of the Baltimore and Sanghvi series but also of Johnstone's series (49.9). The

TABLE 3b

Statistical Analysis of Sex Ratio in Mother-Offspring Combinations

I. Pooled Baltimore-Sanghvi-Johnstone Sample
Total and Partitioned χ^2 Values

CELL (Mother-offspring)	χ^2	D.F.	PROBABILITY	SIGNIFICANCE
O/O	.6310	1	$.50 > p > .30$	
O/A	.0277	1	$.90 > p > .80$	
O/B	.3359	1	$.70 > p > .50$	
A/O	.0106	1	$.95 > p > .90$	
A/A	10.6249	1	$.01 > p > .001$	***
A/B	.5141	1	$.50 > p > .30$	
A/AB	.2225	1	$.70 > p > .50$	
B/O	.2000	1	$.70 > p > .50$	
B/A	.3226	1	$.70 > p > .50$	
B/B	8.2968	1	$.01 > p > .001$	***
B/AB	2157	1	$.70 > p > .50$	
AB/A	.3907	1	$.70 > p > .50$	
AB/B	.9430	1	$.50 > p > .30$	
AB/AB	.3266	1	$.70 > p > .50$	
TOTAL =	23.0621	$14 - 1 = 13$	$0.05 > p > 0.02$	*

II. Categorical χ^2 Determinations on Pooled B-S-J and Independent Samples

SAMPLE	χ_s^2	PROBABILITY	SIGNIFICANCE
1. Offspring of O, A, B, and AB Mothers			
Pooled B-S-J	15.554	$0.01 > p > 0.001$	***
Balto. Pooled Single	4.92	$0.20 > p > 0.10$	
Balto. Pooled Multiple	6.61	$0.10 > p > 0.05$	
Sanghvi (Pooled B-N. Y.)	9.336	$0.05 > p > 0.02$	*
Johnstone	1.003	$0.90 > p > 0.80$	
2. O, A, B, and AB Offspring (irrespective of maternal blood type)			
Pooled B-S-J	10.621	$0.02 > p > 0.01$	**
Balto. Pooled Single	4.317	$0.20 > p > 0.10$	
Balto. Pooled Multiple	4.225	$0.30 > p > 0.20$	
Sanghvi (Pooled B-N. Y.)	8.002	$0.05 > p > 0.02$	*
Johnstone	1.065	$0.70 > p > 0.50$	
3. Mother-offspring Matching Combinations: O/O, A/A, B/B and AB/AB			
Pooled B-S-J	19.455	$p < 0.001$	****
Balto. Pooled Single	7.105	$0.10 > p > 0.05$	
Balto. Pooled Multiple	10.068	$0.02 > p > 0.01$	**
Sanghvi (Pooled B-N. Y.)	11.270	$0.02 > p > 0.01$	**
Johnstone	0.950	$0.90 > p > 0.80$	
4. O/O versus A/A Combinations (χ_1^2)			
Pooled B-S-J	8.897	$0.01 > p > 0.001$	***
Balto. Pooled Single	1.886	$0.20 > p > 0.10$	
Balto. Pooled Multiple	3.671	$0.10 > p > 0.05$	
Sanghvi Bombay	5.57	$p < 0.02$	**[1]
Sanghvi N. Y.	4.93	$p < 0.05$	*[1]
Sanghvi Pooled	10.07	$0.01 > p > 0.001$	***
Johnstone	0.178	$0.70 > p > 0.50$	

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[1] From Sanghvi's calculations.

* = $0.05 > p > 0.02$
** = $0.02 > p > 0.01$
*** = $0.01 > p > 0.001$
**** = $p < 0.001$.

pooled B–S–J totals show a highly significant difference in the sex ratio of the matched mother-offspring combinations (*P* less than 0.001); and even the Baltimore Pooled Multiple and Sanghvi Pooled series taken independently attain the 0.02 level of significance.

Johnstone's report of a high sex ratio in the total offspring of B mothers is not only confirmed in Sanghvi's two series, but also in the Baltimore Rh series, although it did not show up in the Baltimore Paternity series. For the pooled Baltimore series, and also for the pooled B–S–J series, it considerably exceeded the over-all sex ratio, by 2.8% and 3.1%, respectively. Thus the high sex ratio among the offspring of B mothers, like the low sex ratio among offspring of A mothers, contributed to the high significance (*P* less than 0.01) of the difference in the sex ratio which is found to exist among the offspring of the 4 types of mothers in the pooled B–S–J sample.

The AB mothers also exhibit a high sex ratio (55.2) among their total offspring, but the numbers of these, even in the pooled B–S–J sample, are not large enough to indicate whether the difference is real or not.

The B offspring of all classes of mothers exhibit a high sex ratio (54.9). This is primarily attributable to the B offspring of B mothers, and exists in spite of the low sex ratio of the B offspring of A mothers in the pooled B–S–J sample. Thus a study of the data summarized in table 3 indicates that the low sex ratio of all offspring of A mothers and of the A offspring of all mothers is chiefly attributable to the same cause, namely, the low sex ratio of the A offspring of A mothers. Similarly, the high sex ratio of all offspring of B mothers and of the B offspring of all mothers is chiefly attributable to one class, the B offspring of B mothers. The B offspring of A mothers show a low sex ratio, but the numbers are too small to make the difference from the general sex ratio significant; and the A offspring of B mothers show a high sex ratio, but again the numbers are too small to warrant any conclusion.

Father-Offspring Combinations. Since the Baltimore Rh multiple series of father-offspring combinations does not differ significantly from Johnstone's father-offspring series ($\chi_{14}^2 = 7.867$; $.90 > P > .80$), they have been pooled. Table 4 shows that the low sex ratio for all offspring of B fathers (49.0), reported by Johnstone, is confirmed in the Baltimore Rh Multiple Ascertainment series (46.7); but even when pooled, the difference was significant only at the 5% level. No other significant differences appeared in the interrelations of father's and offspring's blood groups and sex.

TABLE 4a

Sex Ratio and Father-Offspring Blood Group Combinations Pooled Baltimore Rh Multiple and Johnstone Samples

		FATHERS									
		O		A		B		AB		TOTAL	
OFFSPRING		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
O	Baltimore	**805**	**53.5**	348	50.0	114	50.9			1267	52.3
	Johnstone	**630**	**52.9**	267	52.4	73	49.3			970	52.5
	Pooled B–J	**1435**	**53.2**	615	51.1	187	50.3			2237	52.4
A	Baltimore	306	50.7	**695**	**52.2**	42	33.3	42	47.6	1085	50.9
	Johnstone	250	51.6	**606**	**51.7**	17	47.1	27	48.1	900	51.4
	Pooled B–J	556	51.1	**1301**	**52.0**	59	37.3	69	47.8	1985	51.1
B	Baltimore	90	56.7	59	59.3	**162**	**46.3**	54	59.3	365	52.9
	Johnstone	52	46.2	21	42.9	**92**	**48.9**	31	74.2	196	51.5
	Pooled B–J	142	52.8	80	55.0	**254**	**47.2**	85	64.7	561	52.4
AB	Baltimore			54	48.1	46	50.0	**10**	**60.0**	110	50.0
	Johnstone			37	45.9	28	50.0	**10**	**60.0**	75	49.3
	Pooled B–J			91	47.3	74	50.0	**20**	**60.0**	185	49.7
TOTAL	Baltimore	1201	53.0	1156	51.7	364	46.7	106	54.7	2827	51.8
	Johnstone	932	52.1	931	51.5	210	49.0	68	61.8	2141	51.8
	Pooled B–J	2133	52.6	2087	51.6	574	47.6	174	57.5	4968	51.8

Mating-Offspring Interactions. Table 5 gives the available data supplied from Johnstone's and the Baltimore Rh Multiple Ascertainment series. Sanghvi did not report on the sex ratio in offspring from different types of mating. Again, because of the lack of any statistically significant difference between them ($\chi_{16}^2 = 9.36$; $.90 > P > .80$), the Baltimore and Johnstone series have been pooled.

As would be expected from the low sex ratio observed independently in all offspring of A mothers and in all offspring of B fathers, there is a marked deficiency of males in the progeny of the mating A ♀ × B ♂. There is also a low sex ratio in the offspring of A ♀ × A ♂. Neither of these differences, nor the distribution as a whole, reaches a level of statistical significance. However, the very high sex ratio from O ♀ × AB ♂ is at the .01 level of significance.

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Johnstone emphasized only the low sex ratio in the progeny of B fathers and the high sex ratio in that of B mothers (table 6A). Allan ('54), observing this, suggested also that "such opposing parental tendencies may also be found to a lesser extent in O and A fathers and mothers." This aspect was unconfirmed by the Baltimore data. In the pooled B–J sample, the dissimilar offspring of mothers classified according to blood group (O, A, B, AB respectively) did not show a significantly different sex ratio from those of fathers of the corresponding blood groups. Allan called attention to the reversed order of magnitude of the sex ratios in the offspring of mothers compared with fathers (B > O > A and A > O > B respectively) found in Johnstone's data; the Baltimore sample (table 6) neither shows the same order as Johnstone's nor any other in which the order in the mothers is the converse

TABLE 4b

Statistical Analysis of Pooled Baltimore-Johnstone Sample

[N. B. Categorical χ^2 tests of Baltimore and Johnstone samples respectively yielded no statistically significant deviations and therefore only the analysis of the Pooled B–J Sample are included here.]

I. Total and Partitioned χ^2 Values—Pooled B–J Sample

CELL	χ^2	D.F.	PROBABILITY	SIGNIFICANCE
O/O	1.2074	1	$.30 > p > .20$	
O/A	0.1152	1	$.80 > p > .70$	
O/B	0.0649	1	$.80 > p > .70$	
A/O	0.1322	1	$.80 > p > .70$	
A/A	0.0148	1	$.95 > p > .90$	
A/B	0.3405	1	$.70 > p > .50$	
A/AB	0.7394	1	$.50 > p > .30$	
B/O	0.1671	1	$.70 > p > .50$	
B/A	5.0239	1	$.05 > p > .02$	*
B/B	2.0861	1	$.20 > p > .10$	
B/AB	0.0920	1	$.80 > p > .70$	
AB/A	0.4237	1	$.70 > p > .50$	
AB/B	5.7032	1	$.02 > p > .01$	**
AB/AB	0.4006	1	$.70 > p > .50$	
TOTAL	16.5090	14 — 1 = 13	$.30 > p > .20$	

II. Categorical χ^2 Determinations—Pooled B–J Sample

a. Offspring of O, A, B, and AB fathers: $\chi_3^2 = 7.0340$, $0.10 > p > 0.05$ NSD
b. O, A, B, and AB offspring: $\chi_3^2 = 1.0668$, $0.80 > p > 0.70$ NSD
c. O/O, A/A, B/B, and AB/AB father/offspring combinations: $\chi_3^2 = 3.6914$, $0.30 > p > 0.20$ NSD

of that in the fathers. The actual orders are O > B > A and O > A > B for Baltimore mothers and fathers, respectively. As might be expected, the Pooled B–J sample follows the Baltimore series, which is larger than the Johnstone series. Even the difference between the sex ratio of the offspring of B mothers and of B fathers so emphasized by Johnstone and by Allan is not statistically significant in the pooled data ($P > .20$). The evaporation of this difference in the course of extending the size of samples points up the need for greater caution in drawing conclusions from supposed differences that lack statistical significance.

TABLE 5

Sex Ratio and Parental Mating Types Based on ABO Blood Groups
Baltimore and Johnstone Samples

MATING	NUMBER OF MATINGS		OFFSPRING				SEX RATIO		
			MALE		FEMALE				
MOTHER-FATHER	BALTO. NO.	JOHNSTONE NO.	BALTO. NO.	JOHNSTONE NO.	BALTO. NO.	JOHNSTONE NO.	BALTO. %	JOHNSTONE %	POOLED %
O × O	420	446	454	412	456	387	49.9	51.6	50.67
O × A	402	401	446	353	408	340	52.2	50.9	51.65
A × O	399	386	410	351	389	350	51.3	50.1	50.73
O × B	135	95	156	81	144	86	52.0	48.5	50.74
B × O	118	71	132	74	110	59	54.5	55.6	54.93
O × AB	48	26	43	39	32	15	57.3	72.2	63.57
AB × O	38	24	42	27	35	25	54.5	51.9	53.49
A × A	357	402	369	370	376	371	49.5	49.9	49.73
A × B	115	84	106	73	126	84	45.7	46.5	46.01
B × A	139	75	151	73	146	63	50.8	53.7	51.73
A × AB	41	27	56	20	45	23	55.4	46.5	52.78
AB × A	33	29	29	28	34	35	46.0	44.4	45.24
B × B	23	16	21	15	26	10	44.7	60.0	50.00
B × AB	8	8	8	8	7	3	53.3	72.7	61.54
AB × B	14	8	17	6	10	7	63.0	46.2	57.50
AB × AB	5	2	4	1	4	2	50.0	33.3	45.45
TOTAL	2295	2100	2444	1931	2348	1860	51.0	50.9	50.97

$\chi_{15}^2 = 19.032$ $.20 > p > .10$ N.S.D.

DISCUSSION

Amid all the natural variance, the data compared here yield, when pooled, a pair of highly significant relationships. In the A offspring of A mothers there is a lowered sex ratio—that is, there are actually

TABLE 6

Sex Ratio of Offspring of Parents Classified According to Blood Group
(Excluding Combinations in Which Parent and Offspring are of the Same Blood Group)

A.

	O				A				B				AB				TOTAL			
	MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS	
OFFSPRING:	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Baltimore	710	52.1	396	52.0	684	50.4	461	51.0	340	50.6	202	47.0	159	54.1	96	54.2	1893	51.4	1155	50.9
Johnstone	347	54.2	302	50.7	352	54.0	325	51.1	126	55.6	118	49.2	65	52.3	58	62.1	890	54.2	803	51.4
Pooled B–J	1057	52.8	698	51.4	1036	51.6	786	51.0	466	51.9	320	47.8	224	53.6	154	57.1	2783	52.3	1958	51.1

Sex ratio of offspring of Pooled B–J Mothers of each blood group versus sex ratio of offspring of Pooled B–J Fathers of same blood group $\chi_4^2 = 2.114$ $.80 > p > .70$ N.S.D.

B.

	ORDER OF PARENTAL BLOOD GROUPS	
	MOTHERS	FATHERS
SEX RATIO:	HIGH MID LOW	HIGH MID LOW
Baltimore	O > B > A	O > A > B
Johnstone	B > O > A	A > O > B
B–J Pooled	O > B > A	O > A > B

fewer males than females; and in the B offspring of B mothers there is a raised sex ratio. When the 5 separate series are examined, these relations appear with high consistency. In both Baltimore series, whether taken by single or by multiple ascertainment, in both of Sanghvi's series, and in Johnstone's series, the sex ratio for the A/A mother-offspring combination is always below 50.0; and in the pooled data, comprising over 2000 recorded births, it is only 48.3. The B/B mother-offspring combination is far less numerous, comprising only 605 births in the pooled data; but its sex ratio (57.7) is the highest of any mother-offspring combination. In only two cases (Balto. Pat. Mult., 52.9; Johnstone, 54.3) does it drop below 55.0; and in both those instances it still considerably exceeds the over-all sex ratios of 50.1 and 51.9 for those series, respectively. Both A/A and B/B combinations exceed the 0.01 probability level.

The pooled B offspring of A mothers also show a low sex ratio (49.2), although the data are not so consistent. However, the number of such births (187) is not large and the statistical variance is consequently high. The pooled A offspring of B mothers conversely show a suggestively high sex ratio (54.2). The number of such offspring (144) is even smaller, and the variance too great to permit any firm conclusion. Nevertheless, there is a suggestion here that the low sex ratio applies to both A and B offspring of the A mothers; and the high sex ratio to both A and B offspring of B mothers.

These are the facts. It remains, if possible, to suggest some sort of biological mechanism that could conceivably bring about these reciprocal shifts in the sex ratio. Recalling that males are produced through the functioning of spermatozoa each carrying a Y–chromosome, and females through the functioning of spermatozoa each carrying an X–chromosome, one may see that what is indicated is clearly some sort of reaction between the maternal genotype, or the genotype of the egg itself, and the relative success of the two types of sperm cell.

The first explanation to spring to mind is naturally that the A offspring of A mothers and the B offspring of B mothers, which exhibit the respectively low and high sex ratios, are homozygous. The data, upon inspection, serve to exclude this possibility. In the first place, homozygotes would also be expected to occur among the A offspring of A fathers and the B offspring of B fathers, but table 4 reveals that the sex ratio in the former class is not low and in the latter class is not high. Moreover, homozygotes are excluded in the classes, B offspring of A mothers and A offspring of B mothers. Among the matings indicated in table 5, homozygotes for A should occur in the progenies of A × A, A × AB, AB × A, and AB × AB. None of these deviate significantly from the over-all sex ratio, and the A × AB and AB × A matings, which according to this explanation should yield identical results, seem to deviate in opposite direction from the average sex ratio. The inviability or reduced occurrence of homozygous A males could not at all account for the low sex ratio in the mating of A × B, which, however, lacks statistical significance. The hypothesis is accordingly insufficient to explain the deviations which do occur and predicts deviations which do not occur.

Because I^O is a commoner allele in the populations studied than either I^A or I^B, most of the A offspring of A mothers must come from matings of A × O and A × A in which the A individuals are heterozygous. Both of these types of mating are expected to yield some O offspring; and in fact all the O offspring of A mothers must come from heterozygous mothers in which an O–bearing egg is fertilized by an O–bearing sperm. Consequently, the sex ratio of the O offspring of A mothers will tell us whether or not the O–bearing spermatozoa, in fertilizing O–bearing eggs in an A mother, produce a lower frequency of males than expected. Table 3 shows that the sex ratio in this class is 51.3, which is certainly not significantly low (P between .95 and .90). One may reason similarly that the O–bearing spermatozoa produce the expected proportions of males and females when fertilizing O–bearing eggs in a B female, for the sex ratio found (53.0) is not significantly different from 51.8 (P between .70 and .50). In fact, table 3 shows that O–bearing spermatozoa yield a normal sex ratio in O, A, and B females, if fertilizing O–bearing eggs. It may further be deduced from table 5 that the O–bearing spermatozoa produce a normal sex ratio when fertilizing eggs carrying A, for the mating A ♀ × O ♂ yielded a normal sex ratio (50.73) in a total of 1500 offspring. The B ♀ × O ♂ has a higher sex ratio (54.93), but the deviation from the mean sex ratio of 50.97 for the matings in table 5 is not significant (P greater than .10). It would see to follow that the observed significant deviation in the sex ratio are not attributable to the O–bearing spermatozoa at all and must consequently be attributable to A–bearing and B–bearing spermatozoa.

We may next examine the data to see whether both O–carrying and A–carrying eggs produced by the A mothers, the majority of whom are heterozygous, are involved, or only one sort; and similarly whether both

O-carrying and B-carrying eggs from the B mothers are involved, or only one sort. In matings of AO females with A- males, the offspring from O eggs fertilized by A sperms cannot be distinguished from the offspring derived from A eggs fertilized by A or O sperms; likewise for the matings of BO females with B- males. But in the mating of AO females with B- males, and conversely of BO females with A- males, the two types of zygotes are phenotypically distinguishable. The AB offspring, in both cases, arise from the egg that carries the allele corresponding to the mother's phenotypic blood group. The B offspring from A mothers and the A offspring from B mothers arise from the fertilization of the eggs carrying O. Table 3 shows that the sex ratio among the pooled AB offspring of the A mothers is certainly not low (53.7); and among the pooled AB offspring of the B mothers it is certainly not high (50.0). On the other hand, the pooled B offspring of the A mothers (sex ratio 49.2) and probably the pooled A offspring of B mothers (sex ratio 54.2) do deviate in the expected directions. These facts inform us that the phenomenon probably arises from the union of O-bearing eggs, in mothers of phenotypes A and B, with spermatozoa bearing A or B. The extreme deviation is found when the sperm carries the same blood group gene as the mother's phenotype, A in A, or B in B.

A mechanism now suggests itself, although for the present it must remain purely hypothetical. It is well known that many individuals carry a dominant secretor gene, *S*, which brings about the secretion of the A or B antigenic substances into the body fluids, such as saliva, lymph, and tissue fluid. In a heterozygous person the diploid cell is protected against highly specific chemical reactions of an enzymatic or immunological type by the presence of both alleles in the nucleus. Following meiosis, however, there come into existence germ cells of a haploid constitution, and thus in a heterozygous mother, eggs of type O are exposed to the A or B antigens. The O eggs in an A mother might then react in an unusual way with spermatozoa also carrying A. One must postulate that in this case more of the O eggs are fertilized by A-X sperms than by A-Y sperms, or else, if fertilization is normal, that more AO-XY than AO-XX zygotes perish. The opposite happens in the case of B mothers. The mechanism implies that there is some modification of the reaction by the alternative presence of the X or Y chromosome; yet there must be a considerable cross-reaction, for in the A mother the O eggs manifest a similar, though weaker, reaction toward the B-X and B-Y sperms, as toward the A-X and A-Y sperms.

The alternative hypothesis that in segregation the A tends to go with the X and the B with the Y, in AO and BO males, respectively, may be ruled out. If it held true, B fathers should in general produce more sons, and A fathers more daughters; but table 4 shows that this is definitely not the case.

This brings us to a situation that is capable of test. Matings of A × A or B × B that produce some O offspring must be between parents both of whom are heterozygous. The mothers of such families must therefore produce O–bearing eggs. One-third of the A offspring of the A × A mating and one-third of the B offspring of the B × B mating are expected to be derived from O eggs fertilized by A and B sperms, respectively. The former should result in a low sex ratio among the A offspring according to the theory, and the latter in a high sex ratio among the B offspring; whereas the O offspring from each mating should exhibit a normal sex ratio. Similarly, from matings of A females by AB males or matings of B females by AB males, the production of B offspring in the former mating or of A offspring in the latter mating will indicate that the mother is heterozygous (AO or BO) and a producer of O–bearing eggs. In the mating of AO ♀ × AB ♂, one-half the offspring of blood group A would come from the fertilization of an O egg by an A sperm, and all of those of blood group B would be derived from an O egg fertilized by a B sperm. Both these classes should exhibit a low sex ratio, according to the theory. In the mating of BO ♀ × AB ♂, one-half the B offspring and all the A offspring would conversely be expected to show a high sex ratio.

There is no test of these relations in the present data, but it should be pointed out that, although the theory satisfies the deviant ratios in the mother-offspring combinations (tables 3), there are certain discrepancies in the father-offspring combinations (table 4). In the latter, the most significant deviation, that of the high sex ratio (64.7) for B offspring of AB fathers, is not inconsistent with the theory. On the other hand, the low sex ratio (37.3) in the A offspring of B fathers is inconsistent with the theory, since such offspring could arise only from the functioning of an O–bearing sperm fertilizing an A–bearing egg produced by an A or AB female.

A possible consequence of the postulated mechanism would be that AO and BO mothers might not only yield abnormal sex ratios in their offspring, but might also show deviations in fertility rates and expected numbers of A and B offspring, respectively.

It is now quite apparent that future work on this problem will have to supply full information, not only in regard to both parents, but also in regard to the sex ratio in each separate category of offspring. A tabulation of this sort has been started, but it will take a considerable time to secure adequate samples for even the commonest categories.

SUMMARY

1. Two Baltimore samples, one from the files of the non-sensitized Rh-negative women and the other from the Paternity Suit files of the Baltimore Rh Typing Laboratory, have been examined for evidence of any relationship between the ABO blood groups and the sex ratio, in comparison with other data on this relationship previously published by Sanghvi (Bombay and New York series) and by Johnstone (London series).

2. From a study of the mother-offspring combinations, a consistent and, in the pooled data, significantly *low* sex ratio was found among all offspring of mothers of blood group A and among the total offspring belonging to blood group A irrespective of mother's type. Both of these are attributable chiefly to the low frequency of males among the A offspring of A mothers, although there is an indication that the B offspring of A mothers also have a low sex ratio.

3. There is a consistent and, in the pooled data, significantly *high* sex ratio among all offspring of B mothers and among the B offspring of all mothers. Both of these are attributable chiefly to the high frequency of males among the B offspring of B mothers, although there is an indication that the A offspring of B mothers may likewise have a high sex ratio.

4. There is a significantly high sex ratio among the B offspring of AB fathers and a low sex ratio among the A offspring of B fathers, in pooled Baltimore Rh and Johnstone data.

5. In preliminary tabulations of the sex ratio in progenies derived from the various types of matings when both father's and mother's blood group was known (Balto. Rh and Johnstone series), a significantly high sex ratio was obtained in the mating where mother was O and father AB. No explanation is offered of this deviation from expectation.

6. From an analysis of the data, it is concluded that O-bearing spermatozoa are probably not involved in the production of exceptionally

high or low sex ratios; and likewise that A-bearing or B-bearing eggs are not involved. The phenomenon seems to arise when O-bearing eggs in females of types A or B are fertilized by spermatozoa carrying A or B respectively. A biological mechanism for this is suggested and means of testing the hypothesis are described.

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CRANIAL ALLOMETRY IN THE GREAT APES[1]

BY EUGENE GILES

Department of Anthropology, Harvard University

DESPITE much recent study of cranial growth and morphology in the primates, there has been little consideration of the analytical technique of allometry, as propounded by Julian Huxley ('32). While some trepidation should always be entertained when attempting to express complex developmental factors by simple mathematical formulations, the positive results of such tests as those made by Moss ('54), Robb ('35) and Reeve ('40), to name but a few, encouraged this author to undertake an examination of allometric relationships in the cranial development of the great apes.

Allometry has also been suggested as a mean of describing osteological change in an evolutionary series, and successful applications of this method have been published by Hersh ('34) on titanotheres, Romer ('48) on pelycosaurs, etc. Since no satisfactory paleontological primate series now exists, the author has attempted to simulate such a series with neontological data in order to investigate the degree of affinity among the members of the great ape subfamily.

The reservation should be made explicit that allometry is used here as a tool descriptive of gross morphology, and as an indication of similarities in developmental patterns. Within these bounds certain objections to the allometric scheme on theoretical grounds are effectively countered by the empirical successes of many researchers.

Essentially, allometry measures the difference in rates of growth or of other size increases. Measurements may be taken either of two dimensions of the same organism or anatomical unit, or of a whole organism and a part thereof. Two separate parts of the organism can be analyzed, and considerable success has been had in applications to the chemical composition of the body (*e.g.*, Forbes, '52a, '52b). The allometric formula $y = bx^k$ is fitted to the data (usually in the linear form $\log y = \log b + k \log x$). The coefficient k is the ratio between the two rates of growth measured; when $k = 1$ the rates are equal, and could as well be represented as simple proportions.

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MATERIAL AND METHODS

At least three possibilities are present in great ape skulls for allometric investigation. The terminology of Huxley, Needham and Lerner ('41) and Simpson ('53), wherein heterauxesis denotes an allometric relationship in an ontogenetic series and allomorphosis the same in an adult series, provides an adequate nomenclature. A sample of 170 chimpanzee, orangutan and gorilla calvaria from the primate collections of the Peabody Museum and the Museum of Comparative Zoology, Harvard University (see table 1) was analyzed for (1) heterauxesis; (2) individual allomorphosis, or allometry between adults of the same population; and (3) genus-form allomorphosis, or allometry between representative adult members of different but related genera. The latter approach has been applied in the same way as paleontologists use lineage allomorphosis, or allometry between members of a phylum in direct line of descent.

TABLE 1

Primate Material

	MALE ADULTS	FEMALE ADULTS	UNSEXED ADULTS	JUVENILES	TOTAL
Pan sp.	40	37	4	36	117
Pan paniscus	2	1	0	0	3
Gorilla g. gorilla	14	10	0	5	29
Gorilla g. berengei	1	0	0	1	2
Pongo sp.	5	7	0	7	19
Total	62	55	4	49	170

The only age-grouping this material needed was a dichotomous one into still-growing juveniles and matured adults. In all species the criterion used was the eruption or non-eruption of the third molar. The utility of this division-marker is apparent; its reliability is attested to by the work of Schultz ('40a) for the chimpanzee, Schultz ('40b) for the orangutan, and Randall ('42) for the gorilla.

Measurements were taken with standard anthropometric calipers to the nearest millimeter. The numerical data were transformed into five-place logarithms, and the straight line best fitting the variates (the slope of which is the allometric coefficient k) was determined mathematically, using the procedure described by Kermack and Haldane ('50). The reduced major axis so plotted has been found a better approximation of the allometric curve than the usual least-squares regression line, though its application has so far been limited (*e.g.*, Parkinson, '52). It also has the advantage of allowing the test devised by Finney ('38) to be adapted to indicate the significance level of the difference between k and unity. Of course, if there is no significant difference, then no allometric relationship should be implied, and it is reasonable to assume that a proportional constancy is maintained between the two variables during growth. The linearity of the logarithmic data is suggested by the coefficient of correlation r and its significance level. Tests of significance between two k factors involve the use of the formula developed by Simpson and Roe ('39).

The 7 measurements used were taken in the following manner. *Prosthion* and *basion* are defined as usual. *Palate breadth* is the greatest separation of the external alveolar borders wherever found. *Palate length* is measured from prosthion parallel to the long axis of the palate to the posterior edge of the alveolar arch. *Cranial breadth* and *bizygomatic breadth* are respectively the greatest breadth of the cranium (avoiding the supramastoid crest) and of the zygomatic arch. *Biporionic axis-prosthion* is the calculated distance from prosthion perpendicular to the biporionic axis at its midpoint. *Nasion* presents some difficulties. While it is clear in the immature forms, by the adult stage it has been completely obliterated. Also, especially in the gorilla, the nasal bones may reach up into the glabellar region. The approximation used, following Randall ('42), was the midpoint of a horizontal tangent drawn to the arches formed by the suture between the maxillae and the frontal bones.

In table 2 the values found for k for each of 4 pairs of measurements are presented together with the significance levels of r and of k. In all pairs the first-mentioned variable is used as x, the second as y. The calculation of b, though a simple one of substitution, has been omitted here because it plays no part in the analysis. Huxley ('32) considers b to be of no particular biological significance. Of the results of groups showing significant linearity and having an adequate sample size about 78% showed significant allometry based upon the Finney ('38) test.

In addition to the analysis of the 4 sets of measurements described in this paper, the author made allometric calculations for two other vector pairs: *biporionic axis-vertex* vs. *biporionic axis-prosthion* and *biporionic axis-vertex* vs. *glabella-opisthocranion*. In the former significant allometric relationships were practically nonexistent, and the results of the latter comparison were almost as meager. These pairs were therefore omitted from the present discussion. However, it is worth noting the lack of allometric development in these dimensions, though it is possible that allometry in *biporionic axis-vertex* vs. *glabella-opisthocranion* was obscured by superimposed bone growth directly effected by muscular attachments and expansions.

RESULTS

Because of sample size limitations, heterauxesis was substantially investigated only in the chimpanzee. The allometric coefficients quantify some of the vectors in the general growth syndrome of large-jawed primates. The k value of 2.774 obtained in comparing *bizygomatic breadth* with *cranial breadth*, for example, gives a numerical value to the higher rate of face-width growth compared with cranial expansion. Such numerical values permit a much more exact description of differences in growth rates among the various dimensions of the skull. The relatively greater downward growth of the chimpanzee face is measured, as is the faster sagittal growth in the palate compared both to the transverse increase in the palate and to the growth in the cranial base.

The data in table 2, describing the rapid postnatal extension of the muzzle in the great apes, provide a very clear-cut example of allometric growth. As mentioned above, the increase in *palate length* has been found positively allometric both with regard to *palate width* and to a measure of part of the cranial base. This situation is likely common to other relatively large-jawed primates (*e.g.*, Huxley, '32, concerning baboons) and is manifested in other mammalian orders (*e.g.*, Robb, '35, Reeve and Murray, '42 for the horse; Reeve, '42 for South American anteaters.

TABLE 2

	PALATE BREADTH VS. PALATE LENGTH			CRANIAL BREADTH VS. BIZYGOMATIC BREADTH			NASION-BASION VS. NASION-PROSTHION			PALATE LENGTH VS. BIPORIONIC AXIS-PROSTHION MINUS PALATE LENGTH		
Chimpanzee	k	P_k	P_r	k	P_k	P_r	k	P_k	P_r	k	P_k	P_r
All groups	1.675	.01	.001	2.075	.01	.001	1.347	.01	.001	.825	.01	.001
All adults	1.184	.05	.001	1.622	.01	.001	1.583	.01	.005	1.266	.05	.001
Male adults	1.377	.05	.005	1.218	*	.04	1.759	**	*	1.077	*	.005
Female adults	.975	*	.005	1.297	*	.01	1.627	**	*	1.378	.05	.03
Juveniles	1.698	.01	.001	2.774	.01	.001	1.285	.05	.001	.761	.05	.001
Gorilla												
All groups	1.552	.01	.01	2.221	.01	.01	1.397	.01	.01	.957	*	.01
All adults	1.878	.01	.01	1.449	.05	.01	1.322	.05	.01	.801	*	.01
Juveniles	1.453	**	.01				1.737	**	.01			
Orangutan												
All groups	1.411	.01	.01	3.872	.01	.01	1.910	.01	.01	1.138	*	.01
All adults	1.421	*	.01	2.593	.01	.01	.890	*	.01	1.256	*	.01
Juveniles	1.356	**	.01	4.686	**	*	2.368	**	.01	.867	**	.01

Note: see text for explanation of column headings; * = found to be not significant; ** = not tested.

The excess of the *bizygomatic* growth rate compared to that of *cranial breadth* is very much greater in the heterauxetic series than in the three series representing adult allomorphosis. Possibly the large *k* factor in the juvenile series reflects an adolescent growth spurt in the mandibular musculature that has promoted ossification in the zygomatic arch. The striking rate of sutural and exterior appositional growth of the zygomatic arch has been investigated by Scott ('54), and also in a longitudinal study by Gans and Sarnat ('51). At the time the adult stage is reached, the zygomatic development, as measured by adult allomorphosis, is for practical purposes merely proportional to the general size increase. Whether the technique employed here is a reasonably accurate one for measuring the magnitude of such "growth spurts" can only be determined by further applications of allometry to other cases and by investigation of the precise relationship of muscle mass to bone production.

Heterauxesis in the young of the gorilla and orangutan, where it could be examined, indicates the same trends, though the statistical significance of these is not proved. It should be noticed how well the allometric coefficients for the *nasion-basion* vs. *nasion-prosthion* measurements reflect the increasing preponderance of downward face-length growth relative to growth along the cranial base in the progression from chimpanzee (1.285) to gorilla (1.737) to orangutan (2.368), the latter developing large jaws coupled to a rather paedomorphic braincase.

Though individual allomorphosis concerns itself with an adult population, it is apparent that it does not divorce itself from the individual's growth, since the *k* factor is determined by the total of the stages each individual reached at the time of growth cessation. In order to justify this coefficient we must assume a category-wide relative growth pattern that is not subject to significant individual variation, a pattern whose implementation but not whose nature is influenced by variation in the "environment" in the sense of total nurture, debilitating diseases, etc., or absolute growth potential. Granting these assumptions, it is possible to consider individual allomorphosis as representing the relative growth rate in, so to speak, the adult stage.

Relevant to this approach is material demonstrated by Huxley ('32) in insects, Reeve and Murray ('42) in the horse, and Forbes ('52a, '52b) in human biochemical studies to the effect that there is a deviation in the heterauxetic line of the data so that two lines forming an obtuse angle provide the best fit. Since the cross-sectional approach necessarily used here with the juveniles was not exhaustive enough to show this directly, an analysis was made between the adult and the juvenile *k* factors to show whether the relative growth ratio underwent such a change during development. Accordingly, the significance between the ratios of all the adults and the juveniles was tested for the chimpanzees; the results are presented in table 3. Again, small sample size prevented similar application to the gorilla and orangutan.

Since the samples were of adequate size for the chimpanzee, a test was made for the differences between the male and female adults' rates; none was found significant.

Current taxonomic practice does not regard the genus as a strictly "objective" category. Mayr ('42) seems in accord with the taxonomist who defined the genus as "in general neither too large nor too small." His own definition is more subtle, but he agrees on the "honest admission of the subjective nature of this unit," viewing the genus as a group of species, of common phylogenetic origin, separated by a gap from other such groups, but "it is to be postulated for practical reasons that the size of the gap shall be in inverse ratio to the size of the group."

Both Simpson ('45) and Straus ('49) give each of the great apes generic rank within a separate great-ape subfamily. As Pocock ('25) observed, many early writers were sufficiently impressed by the similarity between the gorilla and the chimpanzee to assign them only specific difference; however, later workers have separated them, even while recognizing affinities between the two, *e. g.*, Remane ('21), Schultz ('27), Romer ('45), Young ('52). Contrary to this trend, Mayr ('50) has suggested that the gorilla and chimpanzee are but polytypic species that should be placed in the same genus.

Huxley ('32) has noted that taxonomists often pay more attention to differences in proportion than to differences in size. But if differences in proportion, such as the greater dolichurany of the gorilla compared with the chimpanzee, are merely the result of a general size increase acting upon an allometrically developing system, such differences are no more significant than size variations. At least one author (Hersh, '34) has made this observation explicit, proposing that differences in *k* distinguish genera. Even if such value is not placed on allometric similarities and differences, their demonstration can still be regarded as strong indication of affinity. Le Gros Clark ('55) has recently pointed out that the validity of statistical comparisons of anatomical measurements is likely to be greatest in determining the relative affinity of forms known beforehand to be closely related.

TABLE 3

	Significance of difference	*Critical Ratios of Differences*						*Genus-form Allomorphosis*
	ADULTS VS. JUVENILES	CHIMPANZEE-GORILLA		CHIMPANZEE-ORANGUTAN		GORILLA-ORANGUTAN		*k* VALUES
		JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	
Palate breadth vs. palate length	None	1.31	—	2.47	—	0.99	—	2.008
Cranial breadth vs. bizygomatic breadth	.001	1.92	0.76	2.79	3.20	2.89	2.87	—
Nasion-basion vs. nasion-posthion	None	0.48	—	3.77	—	3.43	—	1.349
Palate length vs. biporionic axis-prosthion minus palate length	.005	1.98	3.03	3.62	0.07	1.69	1.22	.787

Consequently, tests were made of the significance of the difference of the *k* factors between chimpanzee and gorilla, chimpanzee and orangutan, and gorilla and orangutan. The coefficients used were derived from the combination of the juveniles and adults. Such combination is questionable where linear allomorphosis and heterauxesis of the same population differ. The usual procedure (*e.g.*, Reeve, '40) has been to disregard the possibility of this difference. However, heterauxesis relies upon fewer assumptions as to its causation than individual allomorphosis, and also usually produces a better fit of the allometric line. Hence, in those categories where a significant difference between these two measures has been shown, the significance of the difference between the species as adults as well as combined groups has been reckoned. Table 3 gives the critical ratios found. Significance at the .05, .01 and .001 levels is assured by critical ratios of 1.96, 2.58 and 3.29, respectively.

In all cases the chimpanzee shows a significant difference from the orangutan when juvenile data are included. Only the adult group in *palate length* vs. *biporionic axis-prosthion minus palate length* is aberrant. This trend of similarities and differences is almost diametrically reversed when the same comparisons are made between the chimpanzee and the gorilla. In the latter pair only the *palate length* vs. *biporionic axis-prosthion minus palate length* is greatly different. (The same measurement taken to include juveniles, barely significant at the .05 level, is the minor exception.)

The gorilla and the orangutan when compared show highly significant differences in their *cranial breadth* vs. *bizygomatic breadth* and *nasion-basion* vs. *nasion-prosthion* rates, thus clearly allying the chimpanzee and gorilla with regard to the developmental patterns exemplified by these two pairs of measurements. The similarity of the muzzle growth rates of the gorilla and orangutan is most likely dependent upon the large size ultimately reached by the two animals. It should also be remembered that the sample size for either of the big apes was not large. It is, in fact, remarkable that so clear a distinction does occur in two significant measurements.

The affinity between the gorilla and the chimpanzee can also be demonstrated by simulating lineage allomorphosis with neontological data, representing in addition to the three forms utilized above, specimens of the pygmy chimpanzee, *Pan paniscus,* and the mountain gorilla, *Gorilla g. berengei.* Such procedure is a special application of genus-form allomorphosis. It should be emphasized that, in contradistinction to adult allomorphosis, neither genus-form allomorphosis as used here nor true lineage allomorphosis has anything to do with the growth of the individual. Lineage allomorphosis is usually demonstrated in a paleontological series, such as Robb ('35) for a horse phylum. Fossil adults at different evolutionary levels are taken to represent average individuals of the populations from which they were drawn, and the rates of change in various dimensions may show allometric relationships. The coefficient for heterauxesis may coincide with that for lineage allomorphosis in the few cases where it can be measured, though Lull and Gray ('49) found this untrue in the ceratopsian dinosaurs. In such cases adaptation has not followed patterns inherent in the individual's growth mechanism. In figures 1 and 2 for each measurement the mean has been plotted separately for both sexes of each species (*Gorilla g. berengei* male only).

In three of the 4 cases the line has been drawn that best represents the trend of the chimpanzees and gorillas. The wide divergence of the orangutan from this allometric line is especially noticeable in the *nasion-basion* vs. *nasion-prosthion* diagram (fig. 1). While not so marked, the deviation of the male orangutan is considerable in the charts for *palate breadth* vs. *palate length* (fig. 1) and for *palate length* vs. *biporionic axis-prosthion minus palate length* (fig. 2). No clear allometric trend was evinced by the *cranial breadth* vs. *bizygomatic breadth* plot (fig. 2), which is explicable if the allometric relationship holding between these two variables is a reaction to the increasing size of the jaw musculature. The sometime eccentricity of the female *Pan paniscus* may in part rest upon the fact that it represents but a single specimen.

Previously we have shown that the gross dimensions of the palate develop allometrically; as a final application of the technique the three bones comprising the palate complex have been analyzed separately. Baer ('54) has studied the loci of growth in rats by vital staining (alizarin red S), and found that individual bones in the cranium are the units of growth. He concluded that they present a physiologically valid subject for allometric study free from the possibility of confounding a number of different growth rates. Moore ('49) found in a juvenile macaque specimen by vital staining that the entire premaxilla was undergoing growth, while the palatine process of the maxilla and the palatine bone were growing only at the transverse suture.

In the present study measurements corresponding to these three segments were taken along the midline of the palate on the 35 juvenile

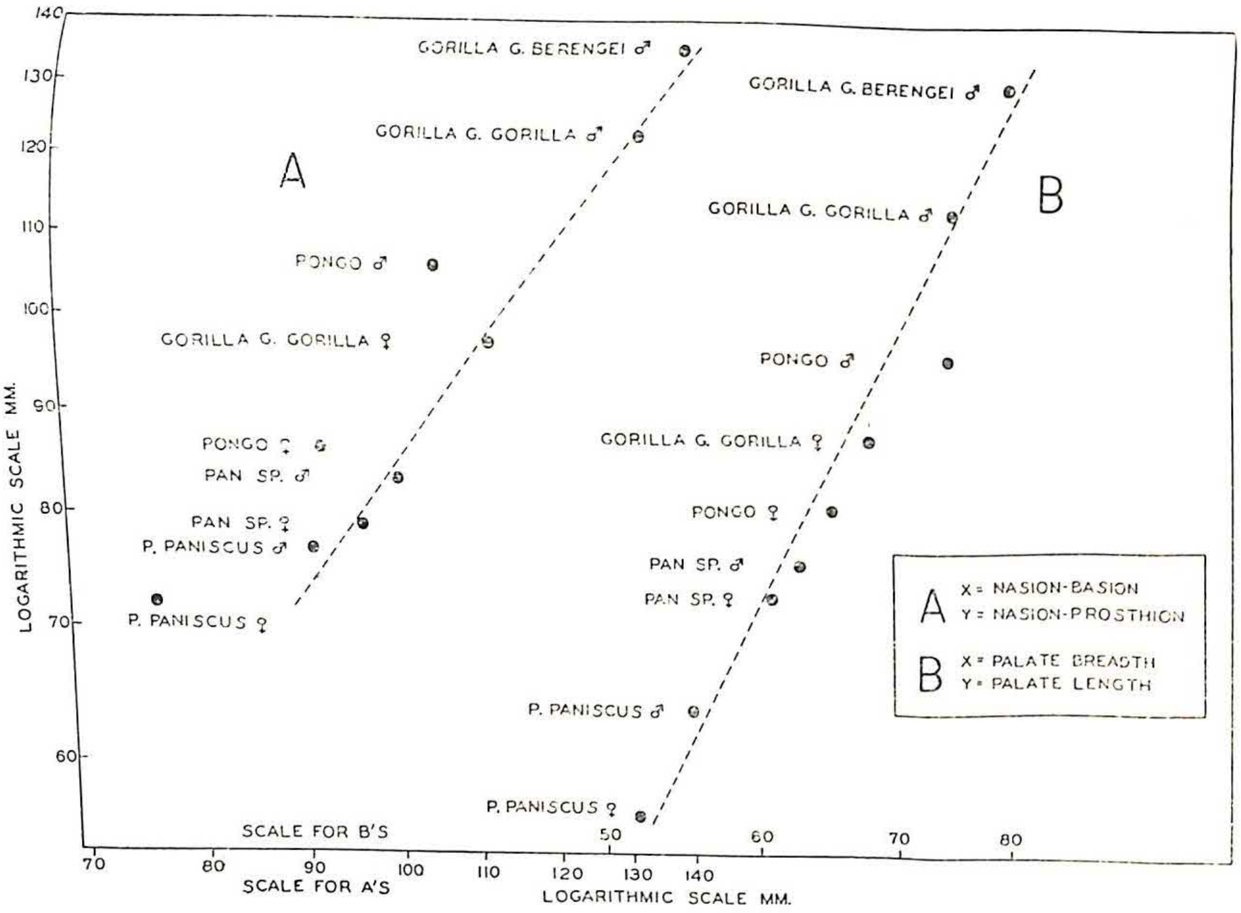

FIG. 1. Simulated lineage allomorphosis lines between chimpanzees, orangutans and gorillas based upon mean cranial measurements for *nasion-basion* vs. *nasion-prosthion* (*A*) and *palate breadth* vs. *palate length* (*B*).

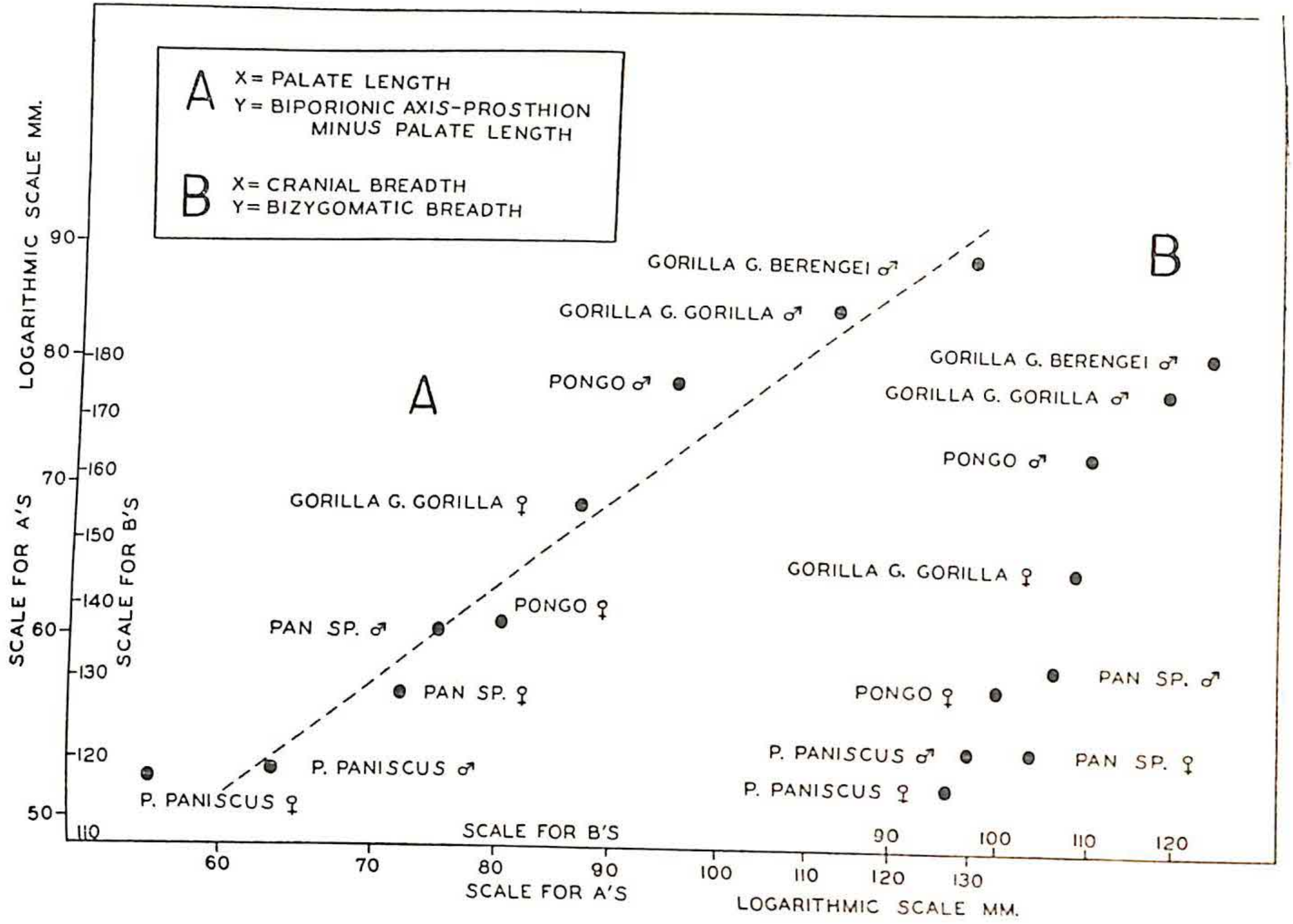

FIG. 2. Simulated lineage allomorphosis lines between chimpanzees, orangutans and gorillas based upon mean cranial measurements for *palate length* vs. *biporionic axis-prosthion minus palate length* (A) and *cranial breadth* vs. *bizygomatic breadth* (B).

chimpanzee specimens. Orthographic representation of these data indicates that increases in the premaxilla and the palatine are roughly commensurate, while the increase of the maxillary portion is much greater than either of the others.

Huxley ('32) and Clark and Hersh ('39) have discussed allometric growth gradients in segmented regions of an animal, such as lobsters' chelipeds. If the palate is considered in a similar light, the growth of each segment can be related to that of the whole palate minus its own contribution. For the 35 immature chimpanzees the premaxilla has a k value of 0.751, the maxilla, 0.968 and the palatine, 2.309. The palatine may be reacting to growth of the posterior pharyngeal musculature in a way similar to that suggested for the growth rate of the zygomatic arch. Both the premaxilla and the maxilla differ significantly from the palatine, but not between themselves. It would appear then that a relative growth gradient exists in the palate and that the rates of growth are of decreasing magnitude anteriorly.

CONCLUSIONS

The application of allometry as a tool suitable for morphological work in physical anthropology is heightened by the precise nature of relative growth rate comparisons which it makes possible. And because it is exponential, it provides a much more flexible methodology than proportions. It is also possible that applications long current in paleontology may become feasible with the increase in fossil primate material.

Systematic groupings cannot, of course, be dependent upon a single classificatory criterion. But close similarities in growth patterns should be given more weight than secondary characteristics such as pelage differences or skeletal rugosity traceable to large muscle attachments, certainly so if phylogeny is stressed in the taxonomic scheme. Allometric relationships found by Lumer ('40) in the domestic dog indicating certain ancestral stocks suggest the utility of differential growth analysis even in such an exaggeratedly variegated species. The present study shows a close affinity between the gorilla and the chimpanzee as opposed to the orangutan, based upon allometric similarities in two analyses quite different in nature.

It is interesting to note that two of the dimensions which best show the difference between the gorilla and chimpanzee on the one hand and the orangutan on the other are those which in the individual allomorphosis lines show no significant difference between the adults and the juveniles (see table 3). This perhaps suggests that the apparent differences in these categories between the chimpanzee and the gorilla are due to similar ontogenetic growth patterns having been at some stage of evolution (so to speak) allowed to manifest different terminal overall morphological configurations through the mechanism of general body volume increase.

A much less certain indication of this is found by comparing the k values previously given for heterauxesis and adult allomorphosis with those determined for the three cases of genus-form allomorphosis (tables 2 and 3). In the three cases the genus-form allometric lines conform more closely with those found for heterauxesis in the chimpanzee. The results are contradictory for the gorilla and orangutan, but the juvenile samples of these two groups are too small to be completely reliable. Since heterauxesis and genus-form allomorphosis differ in kind, no statistical test can be made to determine the significance of this tendency.

Scott ('51) has recently reviewed the question of the process of maxillary growth, noting two general views: one, that the forward growth of the maxilla is primarily the result of sutural growth at the back of the maxilla; and two, that the forward growth is largely anterior apposition.

Scott ('48) elsewhere has noted that the ostium of the antrum in the maxilla appears to be a relatively fixed point (at least in the human being) upon which to base maxillary measurements. However, the use of this landmark in measuring the chimpanzee was found to be incompatible with maintaining undamaged calvaria.

If the palatal growth gradient adduced above has any bearing on the question of forward jaw growth, it would indicate that the premaxillary is less of a center of active growth than the maxillary, which in turn seems to predicate at least a moderate amount of sutural growth in this region.

SUMMARY

The technique of allometry, fitting the formula $y = bx^k$ to morphological variables, has been applied to measurements taken from a sample of 170 chimpanzee, orangutan and gorilla calvaria. Using four basic pairs of cranial measurements—*palate breadth* vs. *palate length*, *cranial breadth* vs. *bizygomatic breadth*, *nasion-basion* vs. *nasion-prosthion*, and *palate length* vs. *biporionic axis-prosthion minus palate length*—relative rates of cranial growth in the great apes were investigated. The use of allometry instead of proportions, as a much more flexible measure of

morphological change during growth, has been discussed, as has its possible application to the measure of adolescent growth spurts. By the use of both allometry of growing individuals and interspecific allometry of adult forms, the gorilla and chimpanzee have been shown to be much more closely related and mutually distinct from the orangutan than the usual tripartite taxonomic classification indicates. The evidence presented suggests that the allometric growth patterns in the chimpanzee would, given an over-all size increase, produce results quite similar to the exaggerated osteological morphology of the gorilla. The palate complex was analyzed with reference to the recent discussions concerning the mode of maxillary growth, and the results would indicate a greater degree of sutural growth than often is allowed.

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RELATION BETWEEN HAIR COLOR AND METALS IN HUMAN HAIR

BY HIDEO KIKKAWA

Department of Genetics, Faculty of Medicine,
Osaka University, Osaka, Japan

INTRODUCTION

SINCE olden times, hair color of human beings has attracted much attention in both the literary and scientific fields. In both cases, however, descriptions of hair color have always been represented by such general terms as white, yellow, red and black, or by special expressions such as blonde and brunet. These are not very satisfactory to scientists, who therefore have felt the need for some other way of describing, which will be advantageous in many respects. Recently we have found a new way, though we must admit that it is still incomplete. This method is based on the fact that there is a certain relationship between hair color and the type and amount of metal contained in the hair (Kikkawa, Ogita and Fujito, '55).

I wish to report in this paper some analytical results which were obtained on new samples of human hair, in addition to data previously published in *Science*.

Before going further, I wish to acknowledge with gratitude the kindness of Dr. G. W. Lasker, who sent me samples of human hair. I am also very grateful to Messrs. Z. Ogita and S. Fujito of this laboratory, who have helped me in many ways.

MATERIALS AND METHODS

Several samples used in this paper were obtained from a barber at Kobe in Japan, where most of the customers are foreigners. A few samples were obtained from myself and from my acquaintances. The rest were selected from the samples sent by Dr. Lasker.

TABLE 1

Metal Patterns of Human Hair of Different Colors

SAMPLE	HAIR COLOR	SOURCE	METAL-PATTERN *					
			Fe	Mo	Cu	Co	Ti	Ni
A	Reddish yellow	White race (English origin, ♀, 17 years old)	2	2	1	0	3	3
B	Yellowish red	The same (23 years old)	2	1	1	0	3	2
C	Dark brown	White race (Baltic, Russian and Jewish origin, ♀, head hair)	3	1	3	2	0	2
D	Reddish dark brown	The same (leg hair)	3	2	2	2	0	2
E	Reddish brown	White race (Scotch and Dutch origin, ♀)	3	3	2	0	0	1
F	Dark brown	White race (German, French and English origin, ♀)	3	2	2	0	3	2
G	Reddish black	White race (Greek origin, ♀)	2	3	3	2	0	1
H	Grey	White race (Origin unknown, old ♂)	1	0	1	1	1	4
I	Yellow	White race (Origin unknown, ♀)	2	2	1	1	4	3
J	Reddish brown	White race (Origin unknown, ♀)	3	3	2	2	0	1
K	Black	Black race (American Negro?, ♂)	3	0	4	1	0	2
L	Reddish dark brown	White race (Origin unknown, ♀)	3	2	2	2	2	1
M	Reddish black	Swedish and Japanese parentage, ♀)	3	1	2	2	0	2
N	Black	Yellow race (Japanese, ♂)	3	0	2	2	1	2
O	Grey	Yellow race (Japanese, old ♂)	1	0	1	1	0	4

* Grades: 0, not or scarcely detected; 1, detected slightly; 2, detected moderately; 3, detected distinctly; 4, detected very distinctly.

The types and amounts of metals were examined largely by the paper-chromatographic method shown in our previous paper (Kikkawa *et al.*, '55). In this method, the analysis of metals can be determined with a very small amount of hair for one sample (30-100 mg). But, for a rigid quantitative analysis, a greater quantity of each sample must be patiently ignited by dry oxidation or by wet oxidation with the use of H_2SO_4, HNO_3 or $HClO_4$. After the treatment, the solution is fractionated by diphenylthiocarbazone (dithizone) dissolved in carbon tetrachloride under a fixed condition of pH. Then, to each fractionated solution is added an adequate organic reagent such as *o*-phenanthroline, dimethylglyoxime and nitroso-R salt, *etc.* Comparing the color of the test solution with that of a standard one, the amount of each metal can be estimated (Parks, Hood, Hurwitz and Ellis, '43; Sandell, '50). The results shown in table 3 were obtained by these procedures.

RESULTS

Figure 1 and table 1 represent results of 15 samples which were obtained from 13 different individuals.

As shown in our previous paper, there is a certain relationship between hair- or skin-color of mammals and types of metals, as indicated in table 2.

TABLE 2

Relationship between Hair or Skin Color and Type of Metal

COLORATION	ASSOCIATED METALS
White	Ni
Yellow	Ti
Red	Mo
Blackish	Cu, Co, Fe

Namely, white color is associated with nickel, yellow with titanium, red with molybdenum, and blackish with copper, cobalt and iron. Based on these findings, we have proposed the hypothesis that hair and skin color of mammals may be composed of metallic complex salts which are coordinated with tyrosine derivatives. Even supposing that this simple assumption is refuted or modified in future, the relation between hair and skin colors and types of metals will remain as a fact. This relation has been ascertained in the present experiment, too. Namely, white hair contains Ni in abundance, in either the white or the yellow race (H and O in fig. 1 and table 1). Judging from these facts, I am safe in the surmise that both D. Eisenhower and N. Khrushchev have abundant nickel in their grey hair.

In yellow hair like A, B and I in fig. 1, titanium is contained in plenty, and the amounts of copper and cobalt are very scarce. From this, it may be concluded that the golden hair of Marilyn Monroe is rich in titanium rather than gold.

Reddish hair like E and J contains molybdenum in abundance, and blackish hair is rich in copper, cobalt and iron, in both the white and the yellow races, and even in the offspring of marriages between them (M). But, it is of interest that the black hair of the Negro (K) contains great amounts of copper and iron, and a very little amount of cobalt, though this result has been ascertained only for one sample.

Now, some interesting points observed in figure 1 and table 1 will be taken up. Sample A represents the hair of a 17-year old girl of the white race and its metal-pattern, and B represents those of the same person at 23 years of age. Both kinds of hair are very alike in color, but A is slightly more reddish than B. Metal-patterns of A and B are also very similar with each other, but the former seems to contain slightly more molybdenum than the latter.

Sample C represents the head-hair of a 32-year old woman belonging to the white race, and D is the leg-hair of the same person. Apparently, D is paler than C in color, and the difference is clearly shown in their metal-patterns, *viz.*, the content of copper in D is less than that in C.

Thus, the metal-pattern varies according to the change of coloration, even in the same person. The most distinct difference may be found in an individual having two types of hair-color like black and white. Figure 2 represents the result obtained from the author's own hair.

Small quantities of black and white hair were picked from my head, and equal amounts (100 mg) of the two kinds were ashed separately. As shown in this figure, white hair contains only nickel in abundance, whereas black hair is rich in copper, cobalt and iron, but contains little nickel. This fact reveals clearly that there is a close relation between the hair-color and the type and amount of metal contained in the hair.

In this paper, as described before, no detailed quantitative analysis was performed. But, in table 3, I have shown for the reader's reference, some data published previously in *Science*, supplementing them with a

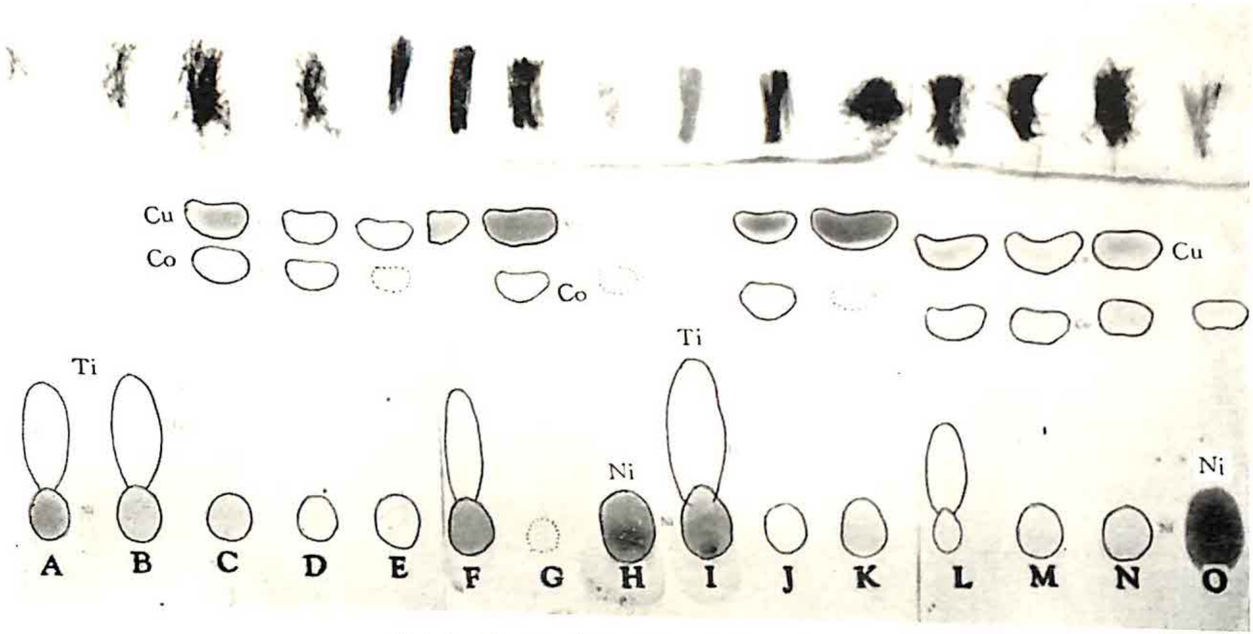

Fig. 1. Metal Analyses of Human Hair.

Samples of human hair of various races and their metal-patterns analyzed by paper-chromatography (see table 1 and the text).

Solvent: Acetone-Butanol-HCl (5: 2: 1).

Reagent: For Cu, Co and Ni, 0.5% rubeanic acid dissolved in 98% ethanol was employed; for Ti, 1% pyrocatechol dissolved in water. In these conditions, however, the detection of Fe is very difficult and that of Mo is impossible. For Mo, 1% potassium ethylxanthogenate dissolved in water was used, but the color faded within an hour. As another method of detecting Fe, Ti and Mo, a supernatant layer of a mixture (butanol 4 + acetic acid 1 + H_2O 5) was employed as a solvent, and 1% yellow prussiate of potash dissolved in water was used as a reagent under acidic state. The results shown in table 1 were obtained by these combined procedures.

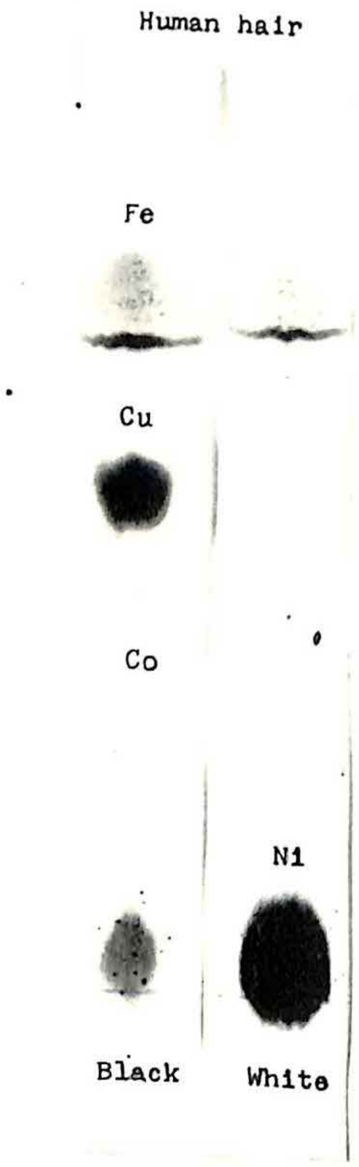

FIG. 2. A paper chromatogram showing the metal pattern of black hair (left) and of white hair (right), both of which were obtained from the author himself (see the text). Solvent: Acetone-Butanol-HCl (5:2:1). Reagent: 0.5% rubeanic acid dissolved in 98% ethanol.

few additional results. In general, the quantitative results fully accord with the results obtained by paper-chromatographic methods.

TABLE 3

Metals Present in Human Hair (μg/10 g of fresh hair)

	METALS *					
COLORATION AND ORIGIN	Cu	Fe	Co	Ni	Ti	Mo
Blonde (Caucasian)	60	11	0	7	120 **	3
Median brown (Caucasian)	80	68	11	19	6	9
Black (Mongolian)	190	290	6	13	—	3
Grey *** (Mongolian)	84	12	—	33	—	—
Black (Negro)	310	200	0	3	0	0

* The ashing was performed by dry oxidation except Ti in Blonde.

** The result obtained from a different sample.

*** Hair mixed with *ca* 70% white and 30% black.

DISCUSSION

Although there is little doubt that the hair color of human beings is determined genetically, the mode of inheritance is very complicated and no definite conclusion has yet been obtained (Davenport and Davenport, '09; Reed, '52; *etc.*). This complexity may be forecast from our studies based on inorganic chemistry, because even at the present stage of research, we are aware of the fact that 6 or more types of heavy metals are concerned with the pigmentation of hair and that their amounts are also responsible for the grades of coloration. Thus, various combinations of these metals, in either types or amounts, may result in very complicated hair colors, and it is easily conjecturable that genetical analyses in such circumstances would be very difficult. In future, however, this difficulty may be overcome to some extent by analyzing metal-patterns of hair in persons who belong to one lineage. Actually, some pioneer investigators have already noticed the phenomenon that if the colors of human hair are different from one another, there is also found a divergence in the types and amounts of the metals contained in the hair (Rothman and Flesh, '43; Flesh and Rothman, '48; Flesh, '48; Smyth, Porter and Bohren, '51).

SUMMARY

Human hairs of various races have different types and amounts of metals, according to the coloration. There is a certain relationship between hair colors and metals, *i. e.*, white color is rich in nickel, yellow in titanium, red in molybdenum, and black in copper, cobalt and iron. When the hair color changes with age or area of the body, the metal-pattern varies accordingly.

ADDENDUM

After this manuscript was submitted, Goss and Green (1955, *Science*, *122*: 330-331) obtained an opposite result: that white hair in animals contains more copper than does black. In fact, an improper wet oxidation frequently gives a result similar to that obtained by Goss and Green. But, by an improvement of methods of dry and wet oxidations, it was found recently that the metal contained in mammalian hair is more abundant than expected. For example, black and white hair of the guinea pig gave the following results (p. p. m. of washed dry hair): black, Cu 268, Co 263, Ni 96; white, Cu 87, Co 38, Ni 638. The details will be published in *Science*.

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FORCE ANALYSES OF HORIZONTAL TWO-HANDED PUSHES AND PULLS IN THE SAGITTAL PLANE[1]

BY GEORGE R. L. GAUGHRAN AND WILFRID TAYLOR DEMPSTER

Department of Anatomy, University of Michigan, Ann Arbor

THIS research was undertaken to elucidate the mechanical factors which are operative when the body exerts pushes and pulls with the hand. No evaluations of the mechanics of body action in this respect are now available. A number of investigators have, of course, measured the magnitude of push and pull forces under various conditions. It has been tacitly assumed that the identification of those postures and movements which will produce maximum operating forces should aid in determining optimum positions of a foot rest, back rest, or hand grip and thus increase the efficiency of man-machine systems. Hand forces have been studied by Lehmann ('27), Garry ('30), Bedford and Warner ('37), Hugh-Jones ('45), Müller and Müller ('49), Wakim *et al.* ('50), and Hunsicker ('55); foot pedal forces by Müller ('36), Koch ('41), Clark and Weddell ('44), Martin and Johnson ('52), and Rees and Graham ('52); and hand and foot pedal forces by Hugh-Jones ('47), Orlansky and Dunlap ('48), and McFarland *et al.* ('53).

On the whole the approach to these studies has been direct, and the resulting data have been empirical. The transfer of derived experimental values even to situations that are apparently related is uncertain, since the principles of body mechanics involved have not been clear.

We are prone to regard all forces which the subject produces as direct muscle force and to neglect completely the inertia of body dead weight in the effort. The position of body mass relative to its support area affects the body anchorage and hence the efficiency of muscular effort. Either the anchorage or the muscular effort may be the limiting factor which defines the maximum force that the body produces. This is an area which calls for critical attention.

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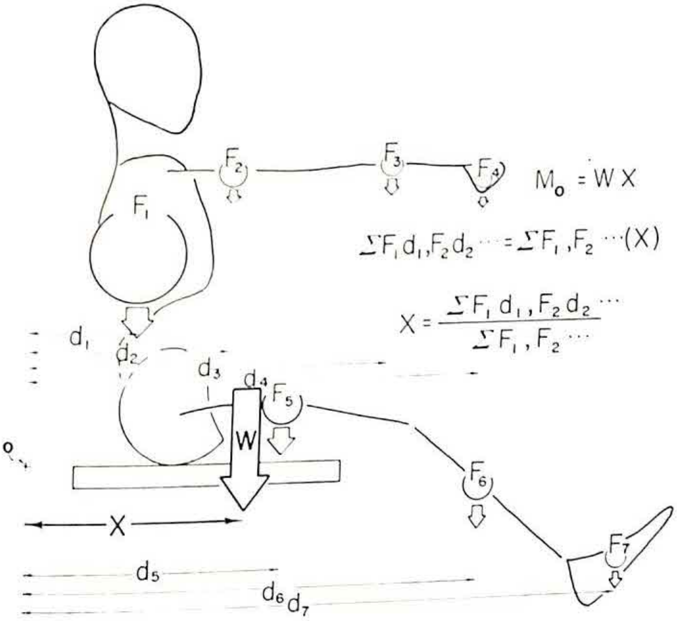
[1] A study conducted under contract with the Wright Air Development Center, (Section of Anthropometry) Air Research and Development Command, United States Air Force, Wright-Patterson Air Force Base, Ohio.

Although our evaluation of the mechanics involved can be little more than an introduction to one class of problem in force relationships, the approach, nevertheless, should point to certain of the fundamentals involved in the application of forces by the body. This study brings to light two basic mechanisms of force production. First, when the trunk is firmly braced against the back of a seat, hand or foot pushes may be exerted as direct compressive forces spanning the hand grip (or foot pedal) and the back rest. With a suitable shoulder harness hand pulls may be exerted as a direct tension between the hand grip and the harness (and its attachments). Second, push or pull forces ordinarily involve the action of force couples; body dead weight when applied at different points on a support creates variable leverages and appreciable torque values. The analysis of the latter mechanism using the principles of rotational mechanics will be the concern of much of this paper.

In the method employed we endeavored to avoid complicated asymmetrical patterns of activity. The method was simply that of having test subjects exert balanced two-handed forces in the sagittal plane and measuring all significant forces which operate in that plane. The problem was to be treated as one involving the balanced forces of statics. To simplify, the subjects initially were symmetrically placed upon a seat without back or foot rests and they exerted steady horizontal push and pull forces in the midsagittal plane. The aim was to determine how the body mass, exerting a vertical component, was used to effect horizontal push and pull forces. Later the influence of foot and back rests was considered.

The human body is composed of a series of articulated links—the extremity segments, thorax, head and neck, etc. Bones form the rigid support for the segments and motions at the joints are rotatory rather than translational in character. (In this study, however, static postures alone are considered and problems of movement are ignored.) Each of the body segments has mass which is subject to the vertical influence of gravity; the degree of this attraction is expressed by the term "weight." The segmental masses, moreover, can be assumed to be concentrated along the respective links at the segment centers of gravity. Thus, for purposes of static analysis, we can visualize a body composed of segmental masses as a related system of vertical force vectors (arrows of fig. 1) which intersect the horizontal at different points. The sum of these segment masses exerts a downward force acting through the common center of gravity of the body; this vector (W of fig. 1), the balance point of the vertical force vectors, is located by a balancing of moments. When segments move to a new position, their masses acquire new positions in space, and both the location of the vertical force vectors of the segments and that of the whole body center of gravity change. Apart from minor shifts of blood within the blood vessels of different regions, the segment masses may be regarded as constant from moment to moment.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$M_o = WX$
$\Sigma F_1 d_1, F_2 d_2 \cdots = \Sigma F_1, F_2 \cdots (X)$
$X = \frac{\Sigma F_1 d_1, F_2 d_2 \cdots}{\Sigma F_1, F_2 \cdots}$

FIG. 1. The distribution of mass in a symmetrically seated individual. A stick figure shows the relative masses (F_1, F_2) of body parts located at their respective centers of gravity: the vertical lines of action are represented by arrows and are located at varying distances (d_1, d_2) from some arbitrary point (O). The heavy arrow (W) represents whole body mass acting at the center of gravity, a distance of X from point 0. *Mo* is the moment of rotation about point 0. The formulae represent one method for determining the location of the whole body *CG* line.

Actually a true balance of forces over a period of time is only approximated. Maintenance of a posture for a protracted period involves irregular volleys of muscular activity and the degree of steadiness depends upon how the forces fluctuate. In mere standing, for instance, the center of gravity of the body sways erratically over the support area with variations according to subject (Hellebrandt *et al.*, '37, '42). Even though these periods of maintained posture truly involve dynamic behavior of muscles, the mean posture may be studied helpfully by static methods. The instantaneous posture record shown in a photograph may be analyzed statically, and such analyses have value, if the photographed posture is representative of some mean body position.

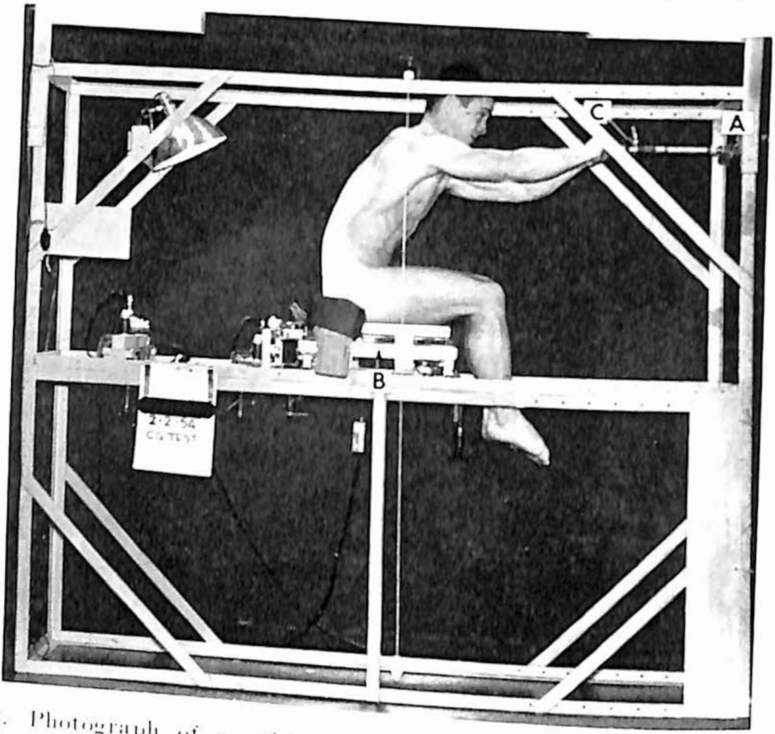

FIG. 2. Photograph of a subject seated in the apparatus and exerting a horizontal midsagittal push at shoulder level. This type of photo was taken for each test at the moment of maximum horizontal force (recorded by gauge labeled A). A spirit level (C) attached to the adjustable bar for force application assured a truly horizontal force vector. A metal frame (B) formed the middle layer of a trilaminate seat.

APPARATUS AND METHOD

To produce records for force analysis, a subject, unclothed, sat symmetrically upon a horizontal seat set in the middle of a rectangular framework (fig. 2). He exerted a maximal steady horizontal push or pull at shoulder height with both hands. At the moment of maximum effort the magnitude of the hand force was noted on a dynamometer and simultaneous photographs were made to record: (1) the subject's posture seen side view, (2) the dials of dynamometers which recorded horizontal reaction forces at the seat, and (3) the dials of other force gauges which showed the distribution of force at the front and rear of the seat. Several arbitrary body postures involving variations in the distribution of the segment masses formed the experimental variable. To reduce individual variability in the record for each posture 10 repetitions were made so that an average could be obtained; all procedures were repeated on three different individuals.

Figure 2 illustrates the basic apparatus. At the upper right of the rectangular frame a horizontal bar supported a 100 kg compression gauge (A) or a 200 lb tension gauge which recorded hand pushes or pulls, respectively. Horizontal bars at the mid-height of the frame supported the basal part of the trilaminate seat. Upon this a rectangular, metal seat frame (B) was supported near its corners by four Dillon pressure gauges, each of 100 kg capacity. These gauges collectively recorded the weight of whatever mass was superimposed; different readings implied an asymmetrical distribution of mass. The seat board, covered by a rubber friction-mat, formed the uppermost lamina.

In figure 3 (right) the seat board has been raised above its basal support to show the four dynamometers (with dial gauges) placed near the corners of the frame which they support. At the sagittal margins of the upper surface of the metal frame, metal channels carried several ½-inch ball bearings. The seat board, which also has metal channels along the lateral edges of its lower surface, rested on the ball bearings. These permitted the seat (upper lamina only) to slide freely in a fore-and-aft direction; free fore-and-aft movement, however, was entirely eliminated by two horizontal mounted pressure gauges (A and B) which are attached to the metal frame.

Forces on the seat acting forward were recorded on the front gauge; backward acting vectors were recorded on the rear gauge. Readings of the 6 seat gauges were recorded directly or through 45° mirrors by two 35 mm Argus cameras, which were activated by solenoids. About 80 lb of lead weighting was attached near the rear edge of the seat surface to prevent forward seat tilting in certain subject postures.

The subject was required to sit on the seat, and for each man the hand-dynamometer height was adjusted to shoulder level. Six pull and

6 push positions were planned for each of the three subjects. In all instances the subject exerted all the force of which he was capable through a symmetrical two-handed push or pull in the mid-sagittal plane. The hand-dynamometer distance varied with subject posture and to this end a series of 6-inch and 3-inch lengths of $^3/_4$-inch pipe were coupled to a T-shaped grip for the application of push and pull forces; a spirit level and mirror (C, fig. 2) were mounted on the bar, so that the subject could be certain of a truly horizontal force. At least 10 records for each posture were required for a full routine; hence, a minimum of 120 records were available on each subject. To avoid fatigue effects, 24 records or less were made at each appointment.

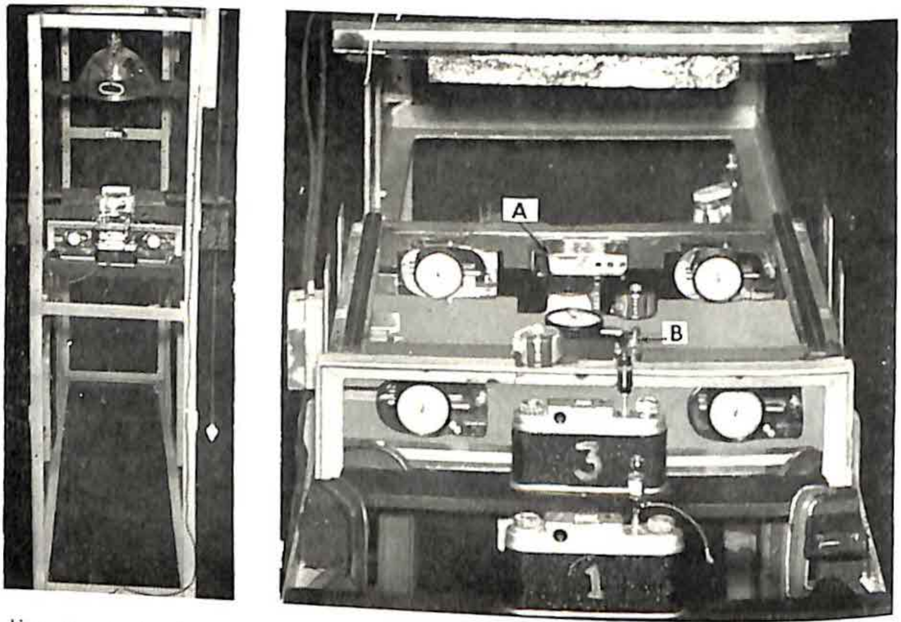

FIG. 3. Left photograph is an overall end view of the apparatus. At the right, a close up end view, the top layer of the seat has been raised to show the middle lamina formed by the metal frame resting on four dynamometers located at its corners. A and B are gauges which recorded fore and aft horizontal counter forces at the seat. In the foreground are cameras (1 and 3) which photographed the dials of the 6 seat gauges.

When the subject was in position for a maximum effort for any posture, an observer watched the hand-dynamometer dial and when the gauge reached a maximum, the operator took an overall side view photograph of body position (like that of fig. 2) using a 120 mm Ciroflex camera, and through the solenoids he made simultaneous records of the

6 seat gauges. Thus, for each test, at the moment of maximum push or pull, there were records on: (1) the force of hand push or pull, (2) the horizontal counterforce at the seat, (3) the distribution of the subject's weight at the front and rear of the seat, and (4) an overall side view record of the subject's posture.

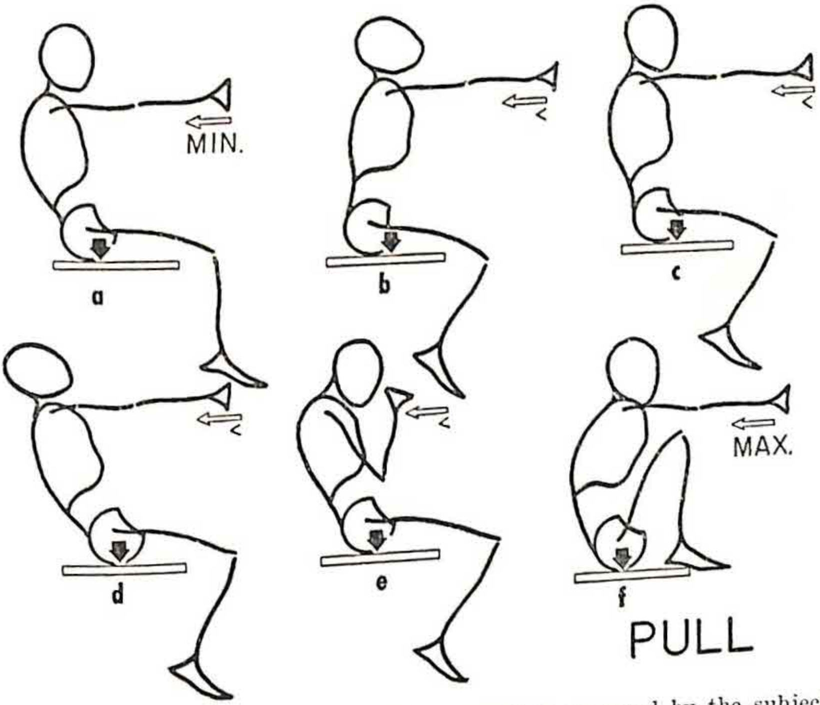

FIG. 4. Stick figures representing 6 test positions assumed by the subject in exerting pull forces arranged in order of force application from minimum at the upper left to maximum at the lower right. The arrows above the seat represent the relative location of the force vector exerted by body mass.

The side view photographs were enlarged and traced on translucent sheet plastic. By superimposing these tracings for all repetitions of a given posture the variations in position and an average position could be determined.

SUBJECT POSTURES

In figure 4 the positions shown as stick figures represent 6 standard seated postures, selected to obtain different patterns of body mass distribution consistent with a fixed height of pull. The vertical line of action of the center of gravity of the body (*vide infra*) is represented in each sketch by the arrow above the seat. The sequence of postures corresponds with the relative strength of pull (min. upper left to max. lower right); in contrast, the relative closeness of the center of gravity of the body to the rear edge of the seat most commonly followed the sequence a-f-e-d-c-b. Occasional variations in this sequence due to differences in individual posture and seat contact positions offered no difficulty, since each force test was actually analyzed individually and the location of the center of gravity was known in each instance.

The postures of figure 4 were as follows. At "a" the subject leaned back passively while holding the hand grip; the center of gravity was well toward the rear. Next, at "f" both the buttocks and the feet contacted the seat, and the doubled up posture was strained; the center of gravity was nearly as far back as at "a." At "e" the subject's trunk was tensed, his arms were flexed and held close to the body, and his knees were tensed and bent; the center of gravity was more forward in this posture. Sketch "d" shows a posture in which the center of gravity was only a little farther forward; the trunk was tensed and strongly inclined backward; and the knees were bent sharply. At "c" the subject sat upright in a strained position with the legs sharply flexed; the center of gravity was a full three centimeters farther forward than in the last position. Finally, at "b," the most forward position of the center of gravity, the subject leaned as far forward as he could and still be able to exert positive pull values.

Figure 5 shows the standard push positions in a sequence of weak to strong values. The mass distribution was superficially comparable with that of the pull positions; there were, however, certain differences in leg and trunk posture, as shown, which the subjects characteristically introduced to facilitate push force. When the original procedures were set up, the 6 pull and 6 push postures were assumed to be identical; later analyses showed that trunk and leg tensions altered the postures in the ways shown in figures 4 and 5. The positions of the centers of gravity shown were based on precise measurements and calculations of moments.

A mechanical analysis of the force system of our tests necessitated a determination of the subject's center of gravity and of the reciprocal vertical reaction force acting upward at the point of effective seat contact. The data for at least 10 repetitions of each posture were averaged and these average force values were used in the calculations of centers of gravity, effective seat contact, and moments of rotation.

The center of gravity was calculated by determining the sum of the moments about the seat contact at the rear pressure gauges. This point (A) is shown in the diagram of the force vectors present in the system (fig. 6). The sum of the moments about A (ΣMA) when the subject pulls is: $Wx_2 + F_4h - F_2d$, which, since the system is in equilibrium, equals zero. From the above equation distance x_2 is obtained:

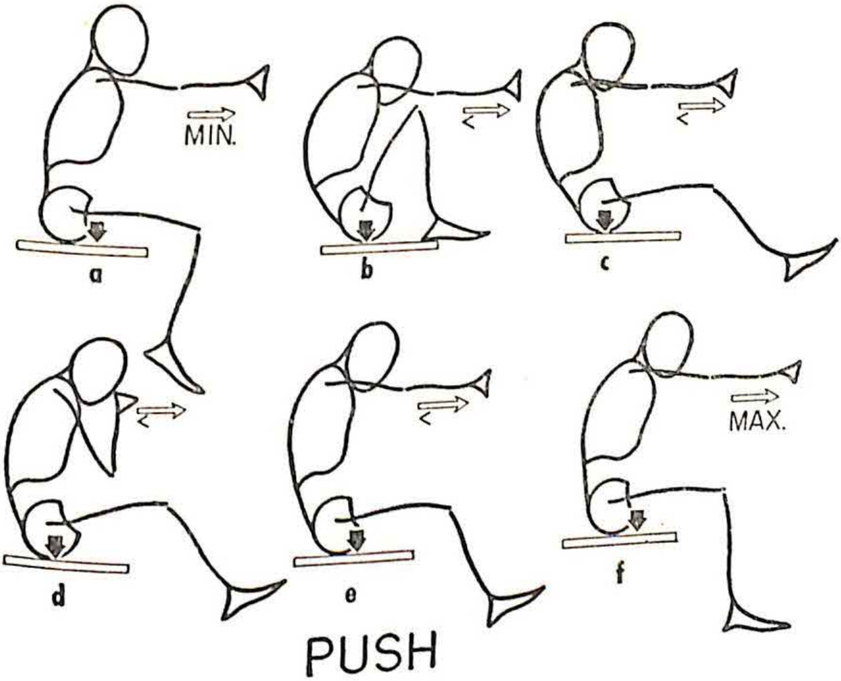

FIG. 5. Stick figures representing the 6 positions assumed by the subject in exerting push forces arranged in order of force effected from minimum at the upper left to maximum at the lower right.

$$x_2 = \frac{F_2d - F_4h}{W};$$

this gives the location of the center of gravity relative to point A. Applying a similar analysis to push situations we arrive at the formula:

$$x_2 = \frac{F_3h + F_2d - F_5b}{W}.$$

Locations of the body center of gravity were checked through the use of cadaver data on the location of segment centers of gravity and on measures of body bulk made on the three test subjects using techniques of limb immersion and a pantograph-planimeter method for measuring trunk volume (Dempster, '56).

The locations of centers of gravity in body segments were known from cadaver data (Braune and Fischer, 1889; Dempster, '56) and equivalent points were plotted as accurately as possible on enlargements of over-all side view photographs of the most nearly average posture in each group of 10 records of the test subject. Estimated masses of segments were based on volume measurements of the test subjects; these masses were assumed to be located at the points marked on the photograph. The whole body center of gravity represented a balance point around which these masses exert either a clockwise (—) or a counterclockwise

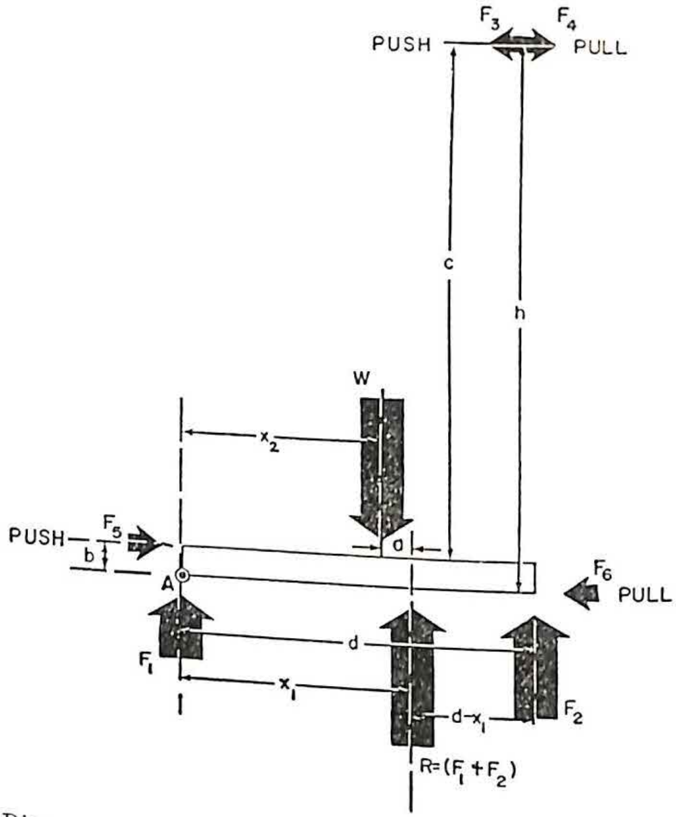

FIG. 6. Diagram of force vectors and moment arms present when the seated subject, without foot or back rest, exerted a two-handed horizontal force in the midsagittal plane. *W* is the mass of the subject acting through the *CG* line and *R* is the reaction force acting upward at the point of effective seat contact.

(+) moment. The moments of rotation were calculated by measuring the horizontal distances from some arbitrary zero point to the segment centers of gravity (fig. 1) and multiplying these distances by their respective masses. Since the force system was in equilibrium, the algebraic sum of the moments divided by the sum of the masses gives the distance of the overall center of gravity from the arbitrary zero point. To get the correct life-size scale, the measurements on the photograph were multiplied by a suitable correction factor. Results of the two methods of checking the location of body center of gravity were ordinarily within a few millimeters.

The point of effective seat contact (the location of vector *R*, fig. 6) was determined by equating the moments of F_1 and F_2 about R (*i.e*, $F_1x_1 = F_2(d - x_1)$ and solving for x_1:

$$x_1 = \frac{F_2(d - x_1)}{F_1}.$$

The significance of this factor will appear in the discussion of results.

GENERAL CHARACTERISTICS OF THE FORCE SYSTEM

In all of the postures muscular action holds the body members in a given spatial position. The individual segment masses are deployed in a characteristic pattern; a separate downward force vector acts at each segment center of gravity. For each posture the resultant force, *i.e.*, the whole body center of gravity, comes to have a specific location relative to the supporting surface. The average distances between the rear pressure gauge contact with the seat and the line of action of the body centers of gravity as calculated for subjects A, B, and C are shown in the second column of table 1.

If the sketches of figures 4 and 5 simply represented various positions of the subject without hand grip contact, the individual's mass would act downward through the center of gravity and would be opposed by an equal upward reaction in the same vertical line. Such a system would consist of two equal colinear forces acting in opposite directions, their resultant being zero.

In the actual push or pull situation, however, the location of the reaction vector, termed here the point of effective seat contact, is not in the same vertical line as the gravity vector. Figure 6 shows that this reaction vector is located at a distance of x_1 from the contact of the rear pressure gauges. The method of calculating for x_1 has been

TABLE 1 *

1	2			3			4			5		
PULL POSITION	DISTANCE IN CM FROM CG LINE TO REAR GAUGE-SEAT CONTACT			DISTANCE IN CM FROM EFFECTIVE SEAT CONTACT TO REAR GAUGE-SEAT CONTACT			HORIZONTAL DISTANCE IN CM FROM CG TO EFFECTIVE SEAT CONTACT			MAXIMUM HORIZONTAL MID-SAGITTAL PULL FORCE IN KG		
	Subject			Subject			Subject			Subject		
	A	B	C	A	B	C	A	B	C	A	B	C
a	24.0	22.8	22.3	27.3	28.2	27.7	3.3	5.4	5.4	3.6	5.3	6.2
f	24.1	24.3	19.8	41.7	44.1	42.0	17.6	19.8	22.2	18.8	19.3	22.8
e	26.0	26.4	28.4	41.9	44.2	42.3	15.9	17.8	13.9	16.9	17.3	14.2
d	26.5	25.8	24.5	41.8	42.7	41.3	15.3	16.9	16.8	16.4	16.5	19.1
c	29.8	28.8	29.4	41.4	43.7	42.4	11.6	14.9	13.0	12.4	14.6	13.3
b	30.3	29.2	31.1	41.9	42.9	42.3	11.6	13.7	11.2	12.4	13.3	11.4
PUSH POSITION										MAXIMUM HORIZONTAL MID-SAGITAL PUSH FORCE IN KG		
c	19.6	22.8	23.4	10.4	10.3	10.9	9.2	12.5	12.5	10.8	13.0	15.5
b	19.8	24.5	21.9	11.9	14.9	13.4	7.9	9.6	8.5	9.2	10.2	9.3
d	23.3	29.3	32.4	11.6	13.4	16.3	11.7	15.9	16.1	13.6	16.9	17.6
e	25.6	29.8	31.9	12.0	13.1	13.6	13.6	16.7	18.3	15.8	17.6	20.1
f	31.6	38.0	38.7	12.4	18.1	17.7	19.2	19.9	21.0	22.4	20.9	23.2
a	33.1	35.8	34.9	29.3	29.8	29.8	3.8	6.0	5.1	4.4	6.3	5.7

* Data obtained from experiments in which three seated subjects exerted maximum midsagittal, shoulder level, horizontal, two handed push and pull forces without the aid of foot or back rest.

considered above; the mean values obtained for this factor are listed in column 3, table 1. In pull position "a" (fig. 4) in which the subject grasped the hand grip and leaned back passively, the effective seat contact was close to the center of the seat. In all other pull positions, however, the subject strained backward and simultaneously applied his weight at a more forward position so that the location of the effective seat contact moved toward the front edge of the seat.

In push position "a" (fig. 5), the subject leaned forward passively against the hand grip; the effective seat contact was now several centimeters forward of the mid-point of the seat and behind the body center of gravity. In all other push positions the subject, as he pushed, concentrated his effort so that, in contrast, the point of effective seat contact moved toward the rear edge of the seat. The subject in pushing ordinarily extended the knees and flexed the thighs from the seat. Thus to produce a maximum force in pushing, he concentrated his effort so that the location of the effective seat contact was moved to the rear of the center of gravity; whereas to effect a maximum force in pulling, he concentrated his effort so that the location of the effective seat contact was moved forward of the center of gravity.

The subject's mass represents a vertical downward force vector acting through his center of gravity; an equal and opposing vector is located at the effective seat contact. These two opposing vertical parallel forces of equal magnitude in the same plane, but not in the same line, form a couple. When a force couple acts upon a rigid body the two opposed coplanar forces, separated by a finite perpendicular distance, cause rotation in their plane of action unless opposed by a couple of equal and opposite magnitude. A full discussion of forces, couples, and moments can be found in such texts on mechanics as Seely and Ensign ('45) and Timoshenko and Young ('40); the problem here, however, is one of applying the principles to the body system.

The couple formed by vertical forces is shown in the sketches of figure 7 by unshaded arrows. The figure at the right illustrates superimposed tracings of side view photographs of 10 repetitions of pull position "d" at the moment of maximum effort; the heavy outline shows the most nearly average position. In the sketch at the left, a wooden block has been substituted for the subject to simplify the force picture. The couple represented by the vertical force arrows tends to rotate the subject (or block) in a counterclockwise direction.

When the seated subject pulled on the hand grip, the dynamometer recorded a horizontal force acting forward at shoulder level. In addition, a parallel force of equal magnitude acting in the opposite direction was recorded at the seat (solid black arrow in fig. 7). The two opposing horizontal forces at the hand and at seat level form a couple which tends to rotate the subject in a clockwise direction. The sense of this clockwise rotation due to the horizontal forces was opposed to that of the vertical forces which simultaneously act on the subject (or block). The tendency of a couple to produce rotation is expressed by the term "moment of rotation" or torque, and its value is derived by multiplying the magnitude of one of the forces of the couple by the perpendicular distance between the two forces. The force and moment values calculated for the pull position illustrated at the right of figure 7 are also shown on the block diagram.

PULL FORCE SYSTEM

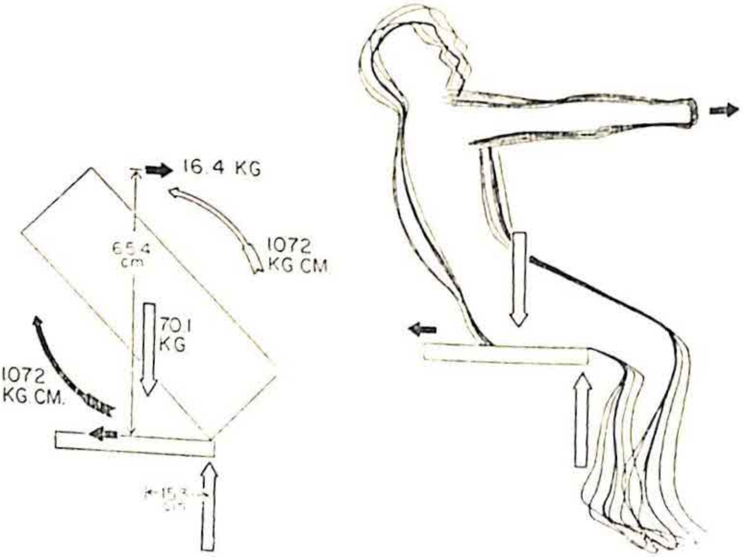

FIG. 7. At the right are represented body tracings of 10 repetitions of one pull position: the most nearly average outline is shown in a heavy line. The vertical forces are shown as outlined arrows and the horizontal forces as solid arrows. At the left a rectangular block has been substituted for the subject and the same force vectors are illustrated with the exact average values for their magnitudes and the average values of their moment arms. These forces form two couples, the moment of rotation of each being shown and the sense of rotation represented by the curved arrows.

Figure 6 represents the type of reaction vectors recorded by hand and seat gauges. For a pull force, the horizontal vector recorded by the hand dynamometer, F_4, or its reciprocal, recorded by the seat dynamometer, F_6, multiplied by the perpendicular distance (h) between their lines of action gives the torque or moment of rotation produced by the horizontal couple. For a push force, the horizontal vector recorded by the hand gauge, F_3, or by the seat dynamometer, F_5, multiplied by the distance (c) between them gives the moment produced by the horizontal forces. The moment produced by the vertical couple is the product of the mass of the subject (W) or the reciprocal reaction at the seat (R) multiplied by the perpendicular distance between their lines of action (a).

It follows from the above that any body action which lengthens the moment arm of the vertical couple for a constant force will necessarily increase the moment produced by the horizontal couple. When the subject strains and adjusts his position of effective seat contact relative to his center of gravity in such a way as to increase the moment arm of the vertical couple, he simultaneously increases the pull or push force at a fixed height above the seat. Analyses of each of the standard pull postures showed the same qualitative relationships recounted here for the one posture figured.

Figure 8 presents a similar analysis of push position "f"; the central outlined figure of the sketch at the right is the most nearly average position, and the stippled halo about this figure represents the range of position for 10 push repetitions. A block diagram analogy of this push posture appears at the left. Here, as in the pull force system, the two vertical forces form a vertical couple (outline arrows), which is balanced by the two horizontal forces of a horizontal couple (black arrows), *i. e.*, same moments in kg cm. In contrast to the pull system, the line of action of the effective seat contact was to the rear of the line of action of the subject's mass, the lines of action of the horizontal forces were reversed and the sense of the moments of rotation produced by the couples were reversed.

On the right hand sketch of figure 8 circles represent the relative masses of individual body parts; arrows directed downward indicate the lines of action of these masses. The masses were calculated from measurements of bulk made on the subject, and their vectors were located at centers of gravity based on cadaver data. As explained earlier, data on segment mass provided a means of checking the accuracy of the calculated locations of action lines of whole body centers of gravity. A calculation of the counterclockwise moment produced by the mass of the trunk about the center of gravity should be equal and opposite to the clockwise moment produced by the sum of the masses of all other body segments. These moments for the subject and mean push position illustrated were: + 342 kg cm and — 340 kg cm, respectively. Similar calculations for all selected positions were used as a check for the location of whole body centers of gravity.

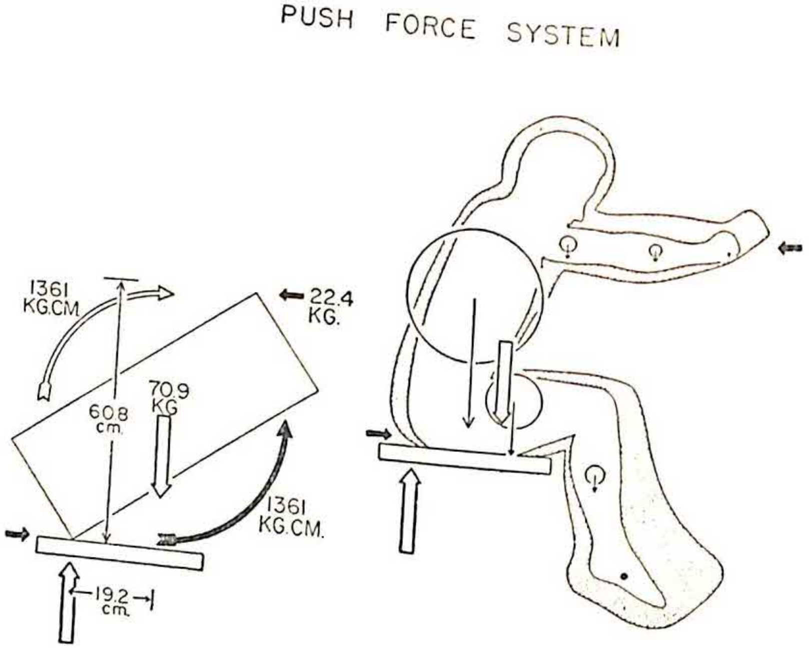

FIG. 8. At the right the stippled halo represents the range of body positions for 10 repetitions of one push posture; the most nearly average position is shown in solid black outline. The relative size of the masses of body parts is shown by the diameter of the circles and their lines of action by the vertical arrows.

Figure 9 is a block analogy of the push and pull force system, the heavy solid line in the left sketch shows a block tilted forward corresponding to a push position; at the right the block represents a pull position (tilted backwards). The horizontal forces recorded for a push or pull (black arrows) form the horizontal sides of a rectangle and the distances between these forces, the moment arms of the couple, form the vertical sides of the rectangle. Hence the area of rectangle *A*, the stippled area, is a visual expression of the moment of rotation produced by the horizontal couple. Similarly, area *B*, crosshatched, represents the moment of rotation produced by the vertical couple. Area *A* is equal to area *B* in a balanced system. Thus the moment of the horizontal couple has the same magnitude as the vertical couple but the sense of its rotation is opposite. If the block tilts farther forward moving the center of gravity forward, or tilts backward, the distance between the two vertical (constant) forces increases, and area *B* becomes greater. If the force system remains in equilibrium, there must be an equal increase in area *A*. Since the moment arm decreased with increasing tilt the horizontal force must increase notably for the equilibrium situation.

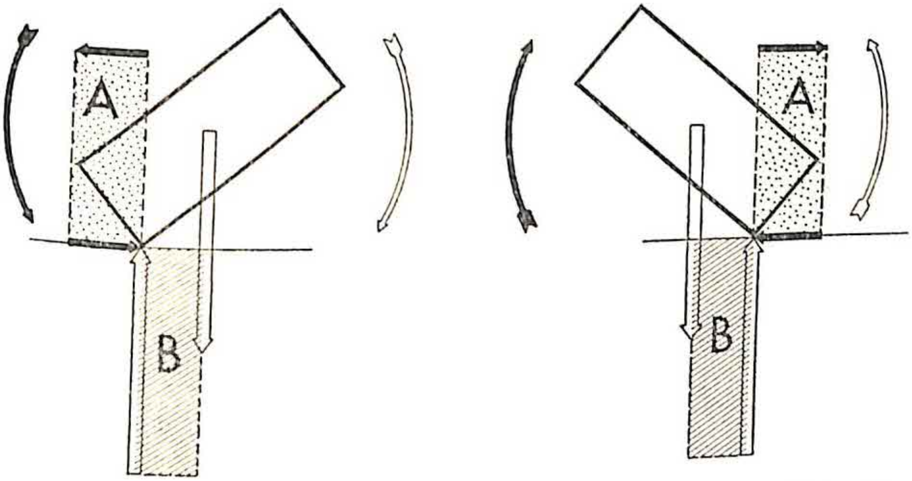

FIG. 9. In these figures a wooden block is substituted for the subject. The vertical and horizontal force couples with their moments of rotation are shown in the push system at the left and the pull system at the right. The moments of rotation are shown as rectangular areas (A and B); their magnitudes in a balanced system are equal and their directions of rotation are opposite.

Under the conditions of the experiments the distance between the line of pull (or push) at the hand grip and the line of opposing force recorded by the compression gauge at the seat was fixed, *i. e.*, the subject could not alter the moment arm of the horizontal couple. Neither could he change the magnitude of his body mass; hence, the size of the vertical counterforce was fixed also. The only changes possible for the subject in order to increase hand force, were a lengthening of the horizontal moment arm through: (1) a change in the position of his whole body center of gravity and (2) an adjustment of the point of effective seat contact. A simple tilting of the block moves the center of gravity relative to its lower contact corner. The subject, however, has a broad area of buttock (and foot) contact with the seat. The force per unit area (*i. e.*, stress) can concentrate at different parts of the area of contact; normally for the simple rest position the stress will be highest at the ischial tuberosities. Through muscular effort and by virtue of a contact with the hand grip the subject may bend certain joints and extend others and in this way he may concentrate the point of application of force at the seat either forward of the center of gravity (toward the hand grip) or behind it (farther from the hand grip). He thus lengthens the moment arm between the line of action of the body center of gravity and that of the effective seat contact. These changes in body tension which result in different points of force application can often be effected with very little change in the location of the whole body center of gravity.

THE MUSCLE CONTRIBUTION

Figure 10 illustrates muscle tensions which were observed by palpation. In pushing there was a general tension of arm, chest, and anterior abdominal wall musculature. Tension was felt also in the hip flexors and knee extensors. Extension of the legs and moving the center of gravity forward tended to increase both the clockwise rotation and the magnitude of the push force; thigh flexion which decreased thigh contact with the front of the seat moved the effective seat contact to the rear (*i. e.*, to the ischial tuberosities). In pulling, tension was felt in the arm, shoulder, and deep back musculature. Activity was noticed in the hip extensors and knee flexors. The former moved the effective seat contact forward, off the ischia, to the thigh contact with the seat; the latter action tended to prevent pulling the body off the seat by moving the center of gravity to the rear. In both positions these movements of body parts effected by muscle actions increased the moment arm of the vertical couple.

MOMENTS AND FORCES

On the basis of this analysis of the mechanics of our system, the subject should obtain the largest pull or push values when the moment arm of the vertical couple is greatest and the smallest pull or push values when the moment arm is least. Figure 11 illustrates the pull

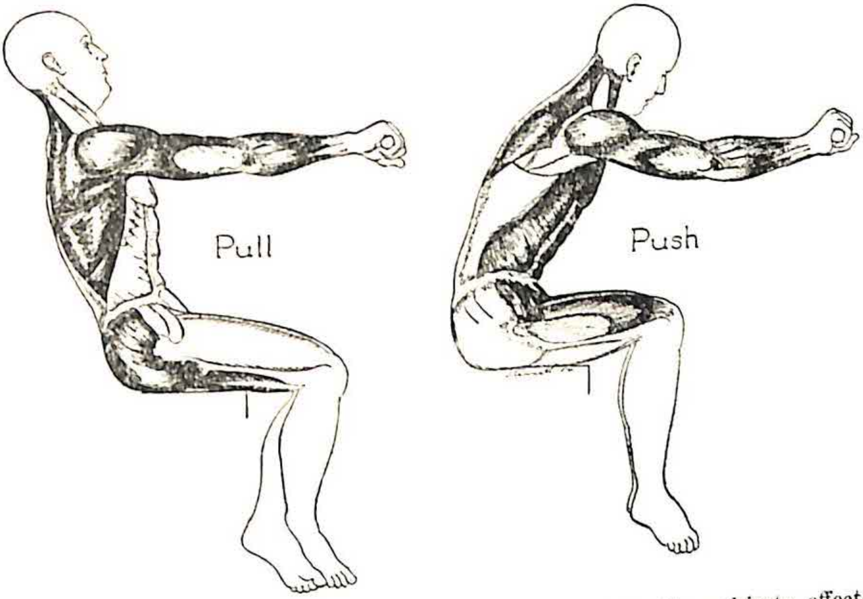

FIG. 10. Muscle tensions observed by palpation when the subjects effected horizontal pull and push forces.

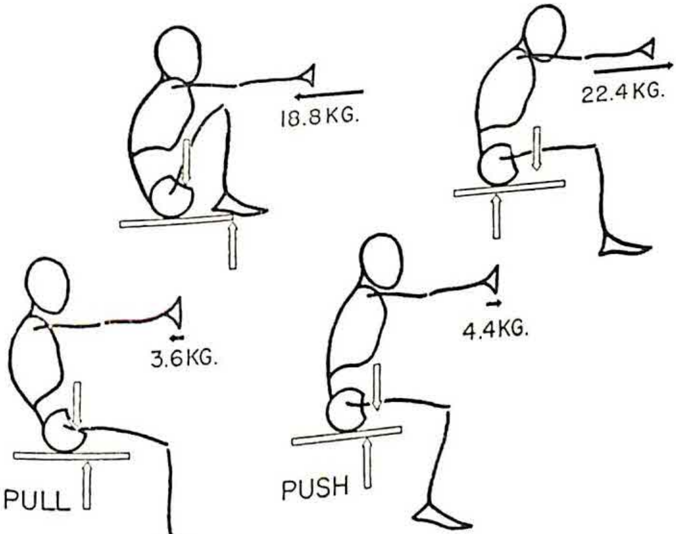

FIG. 11. Stick figures showing the push and pull positions in which a subject effected the indicated maximum and minimum horizontal force values.

and push postures in which the subjects obtained maximum and minimum force values (cf. table 1). In pull posture "a" (lower left) in which the subject leaned back passively grasping the hand grip and in push position "a" (lower right) in which the subject leaned forward passively on the hand grip, the moment arm of the vertical forces was minimal; notice that the horizontal forces were correspondingly small. In pull position "f" (upper left) and push position "f" (upper right), however, there was a considerable distance between the vertical forces (*i.e.*, the moment arm was maximal) and there was a correspondingly greater value of the horizontal force. The mean values for the moment arms of the vertical couple are listed in column 4 of table 1; the magnitude of the horizontal forces are listed in column 5. Columns 4 and 5 of table 1 show an increase in the size of the horizontal forces corresponding to an increase in the length of the moment arm of the vertical couple.

The hand dynamometer was set at a convenient height at about shoulder level for subjects A and B; the same height was used for each subject although A was somewhat shorter in trunk height than B. Subject C was tallest in trunk height and he could use only one push and two pull positions at the same height as the other two men; consequently, the dynamometer height was set three inches higher for 5 pushes and 4 pulls.

When the moment arms of the vertical couple for a subject were plotted as ordinates against the related horizontal forces as abscissae, a straight line plot was produced in each instance (fig. 12). The slopes of the curves for either pushes or pulls indicated that subject A produced a greater horizontal force for a given horizontal moment arm than subject B. Line *C* of the graphs was drawn through points resulting from a higher dynamometer position than for the other two subjects; one push value and two pull values (squares) fell well to the right of the line—these represented the lower dynamometer position mentioned above. If only values for the same dynamometer hight are considered, subject C produced more force that A who, in turn, produced more than B for a given moment arm.

All the moment-force data on the three subjects thus were mathematically consistent and confirmed the principle that the magnitude of horizontal force is proportional to the moment arm of the vertical couple for a given body weight irrespective of the body posture or the type of muscular action put into the effort.

GENERAL PRINCIPLES

The force system that has been analyzed truly consists of a closed chain (fig. 2) with an organic and inorganic component. The former consists fundamentally of the body links between the seat and the hand grip (*i. e.*, pelvic region and trunk, shoulders and the parts of the free limbs) and the other formed by the frame which supports the seat and hand grip (*i. e.*, hand grip, dynamometer, dynamometer support bar, the right hand uprights to the mid-level horizontal, the horizontal support and the seat with its fore-and-aft contacts with the frame). A detailed consideration of the vertical and horizontal force system operating in the support and framework is uncalled for here; it should be appreciated that any pull or push forces are opposed by stresses within the material of the framework. It is only through the action of counterforces (measured by the several dynamometers) that the body can express forces on its environment. In the rotational system considered, muscular tensions simply concentrate the stresses to the pelvis

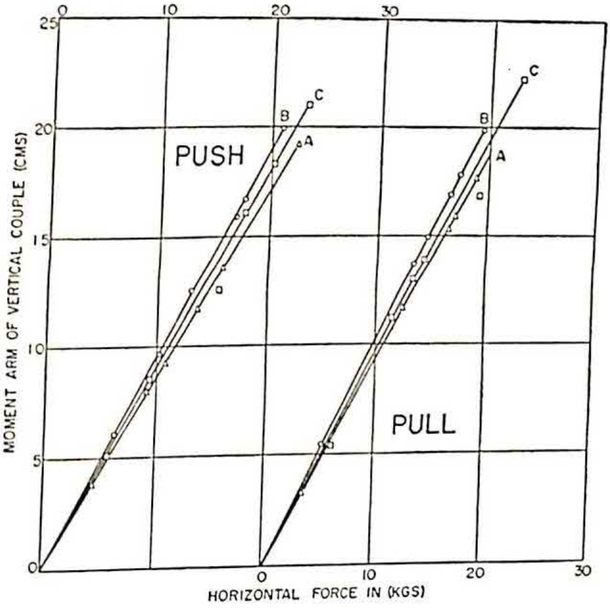

FIG. 12. The average magnitude of horizontal forces effected by three subjects (subject A, triangles; B, circles; C, squares) plotted against the respective average moment arms of the vertical couple for 10 repetitions of 6 different push and 6 pull positions.

or to the femora and thighs in different patterns. The contact with the hand grip as well as with the seat is a necessary condition for the development of the couples which have been treated above.

USE OF FOOT REST

The same principles apply when a foot rest is utilized. The sketch at the left of figure 13 illustrates the force system involved in the use of a seat plus a foot rest in horizontal midsagittal pulls. In the position shown the subject pulled his maximum, transferring the point of effective contact from the front edge of the seat to the foot rest. The magnitude of the pull force for a test subject in this situation was 47.7 kg (horizontal black arrows in figure), the moment arm of the couple formed by the horizontal forces was 100 cm, and the moment of rotation produced by this couple (stippled area) was 4770 kg cm. The

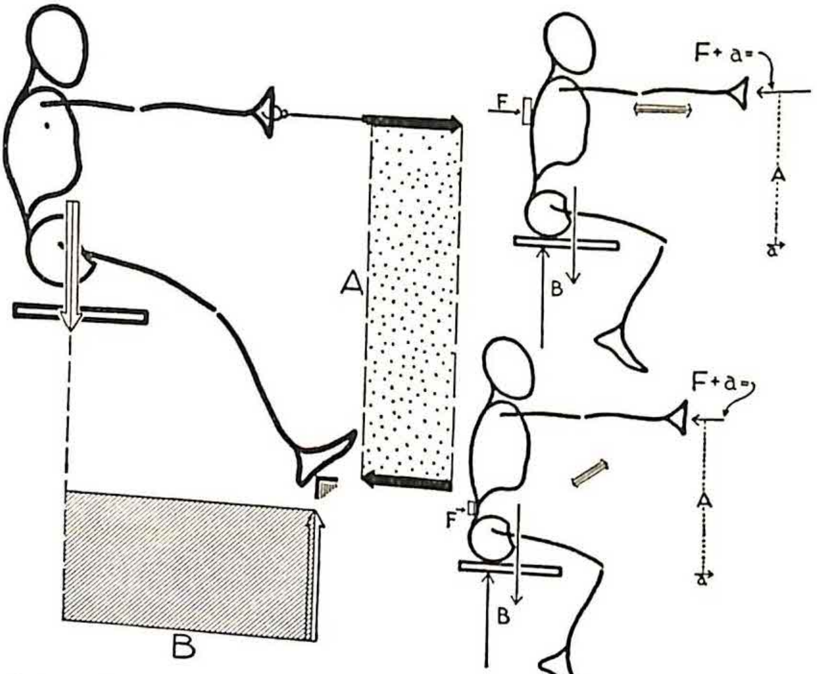

FIG. 13. At the left is a stick figure diagram illustrating the force vectors present when the subject utilizes a foot rest in producing hand pulls; at the right are two sketches showing the force vectors present in a push system utilizing a back rest at two different heights.

subject's weight was 68.2 kg and was opposed by a reaction force of the same magnitude at the foot rest (vertical arrows). The moment arm of this vertical couple was 70 cm and the resultant torque was 4774 kg cm. The moments produced by the two couples (areas *A* and *B*) were, within the accuracy of measurements, in equilibrium.

The mechanics of this system is identical to that involved in the earlier tests utilizing seat alone. Here, however, the length of the moment arm of the vertical couple was increased by moving forward the effective body contact from the seat to the foot rest. It is to be noted also that the point of body contact was lowered. For a more effective use of dead weight, the foot rest should have been located closer to the horizontal level of the hand pull. It will be apparent from the diagram that push forces on a foot pedal will be maximal for the same conditions which bring forth maximal hand forces.

USE OF BACK REST

The back rest introduces a wholly new problem. In a series of tests, a back rest was placed at sacral, waist, xiphoid, and shoulder levels. Horizontal forces for one subject resulting from pushes at shoulder height were: 19 kg, 30 kg, 33 kg, and 40 kg, respectively. Two of these positions, waist and xiphoid, are shown by the sketches at the right of figure 13. Essentially the same torques due to body dead weight operated whether a back rest was utilized or not and the hand force would be proportional to the moment arm of the vertical couple, but an additional factor entered the force system when a back rest was used. The back rest supplied a stabilizing support against which upper limb and trunk muscles could operate to exert a direct horizontal pressure along the body links between hand grip and back rest. For the subject tested, the horizontal push force utilizing a back rest at waist height was increased by almost 20 kg over the value obtained by the use of dead weight alone; the value of the increment increased as the back rest was raised to shoulder height.

In the lower right sketch of figure 13 the couple involving the subject's dead weight produced a force "a" and the action of arm and trunk muscle tensions resulted in a direct horizontal pressure "F"; to produce force "F," the subject elevated his shoulders, arched his back, and tightened the extensor muscles of the arm to increase the compressive force acting obliquely across the arched strut between the back rest and the hand grip. The sum of the two horizontal components (F and a) represented the magnitude of the horizontal hand push.

If a shoulder harness were attached to a back rest, pull forces could be augmented in a reciprocal way. Now the pull force proportional to the horizontal moment arm of the vertical (weight) couple would be supplemented by muscle tensions operating along the chain: hand grip, arm and shoulder, harness and back rest.

OTHER APPLICATIONS

Although measurements were not extended to other situations it is apparent that the two principles outlined above (dead weight couples, and direct forces due to bracing) are not limited to the seated posture. A sidewise standing push or pull at shoulder height will be greater if the feet are planted far apart. If the near foot is lifted and the body weight is centered well ahead of the implanted foot, the push will be augmented. Conversely, if the rear leg is lifted and the near leg replanted firmly, the body weight acts well behind the near foot and a pull force will be high. Again, a lower height of push or pull will produce greater hand forces till foot friction with the ground forms a limiting factor. The addition of a tension or compression brace, *i. e.*, an inorganic linkage from hand to trunk, will permit the additional action of muscular forces across the upper limb links. For the seated operator a compressive brace at (or above) hip joint level will permit high foot pedal forces; if the trunk leans backward to produce a vertical force couple the back rest will need to be at perhaps lumbar level (Weddell and Darcus, '47; Rees and Graham, '52) for highest force values.

Further study of asymmetrical one-handed or one-footed static actions should bring out additional information concerning bracing and the action of couples in planes other than the sagittal; dynamic problems also warrant attention.

SUMMARY

This study was an investigation of a static force system of the closed chain type between test subjects and a rigid framework; the animate and inanimate components were linked at both the hand and seat contacts. A nude subject, symmetrically placed on a seat without foot or back rest, exerted a steady two-handed pull or push at shoulder level in the mid-sagittal plane. Suitable instrumentation provided a means of recording: (1) the subject's posture at the moment of a maximum force, (2) the distribution of vertical forces at the front and rear of the seat, and (3) the maximum horizontal reaction forces at the hand grip and at the seat. Three subjects were used and 10 repetitions were made of all

measurements in each of 6 stereotyped push and 6 stereotyped pull postures. Since pushes and pulls are possible only in a closed system, either couples acting in opposite sense or directly opposing forces can be involved. Two force couples, resulting in equal moments of rotation but acting in opposite directions, were recognized in the system. One couple, involving forces due to body weight, was composed of a downward force vector acting at the body center of gravity and an upward counterforce localized at the effective seat contact. The other couple involved the horizontal force exerted on the hand grip and the horizontal counterforce at the seat. The data from the study show that the subject, by muscle tensions, during hand pulls or pushes can change the location of the focus of a seat contact anywhere between the ischia and the lower thigh and thus alter the moment arm of the vertical force couple; the magnitude of the horizontal force is directly proportional to the moment arms of the body weight couple.

The introduction of a foot rest changed the point of seat contact from the seat to the foot rest, increasing the moment arm of the vertical couple and causing a greater resultant horizontal force. This modification, however, did not alter the basic mechanics involved. The use of a back rest, in contrast, provided a means by which the subject could exert a direct compressive force by tensing muscles against the resisting contacts to augment force values obtained by dead weight alone.

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BOOK REVIEWS

The Human Animal. By WESTON LABARRE. University of Chicago Press, 1954. Pp. xv + 372. $6.00.

In this attempt to formulate a unified anthropological view of man, the two main categories of interpretation are man's biological evolution and the orthodox psychoanalytic theory of human behavior.

As an anthropologist, LaBarre is interested in culture, interpreted as a function of biological evolution. In fact, he is so insistent on the biology of culture and human behavior that he refers to man time and again as "the human animal." In depicting man's organic evolution he makes extensive comparisons with other species, and particularly with the apes. One wonders whether apes today more closely resemble the behavior of some common ancestor than we do?

All mankind is one species, says LaBarre, with the important differences between "races" being functional or cultural, rather than biological. Culture is "man's ecology." It has freed man from biological evolution; continued evolution for him is cultural. ". . . the emancipated hand has emancipated man from any other organic evolution whatsoever. With man, genetic evolution and organic experiments have come to an end" (p. 89). An important aspect of cultural evolution is its "fantastic speed" when compared to biological; in addition, man has to pay no genetic price in physical specialization for his cultural evolution.

Chapters 10 and 11 are concerned with the analysis of communication, and the change from phatic to symbolic. The former gives "information about an individual animal's state of mind" (p. 57), and commits LaBarre to anthropomorphism (pp. 8, 18, 57, 165, 334); the latter refers to language. The development of language is related to biological evolution: language could have been developed only by an animal with man's organic evolution. LaBarre demonstrates quite effectively that our conception of reality is determined for us by the structure and concepts of our language. Thus language, which is the means to knowledge, is also effective in forever concealing from us the picture of reality as we would find it were we free of language. The effect of this cogent argument is later dissipated, however, when LaBarre tries to show that language is basically emotional rather than cognitive.

Cultural behavior, which is distinctly and singularly human, is interpreted by LaBarre in terms of orthodox psychoanalytic theory.

Everything centers around the oedipal situation and the permanent breast. Relations between the sexes, and differences in behavior between the sexes are biological-psychoanalytic: for example, generalization is male, but "biologically, women are closer to realistic particulars" (p. 212). It is "small wonder" that women in general are more "psychological-minded than men . . . They have to be, biologically." (p. 215). LaBarre's hatred of the father and adoration of the mother is not based on empirical investigation but on faithful acceptance of the word of his own god, namely Freud. One wonders to what extent this biological-psychoanalytic theory is or can be useful in relation to further study. For example, in what way will the study of human culture be advanced by applying individualistic concepts to collective phenomena? This is what LaBarre does when he concludes that the wisdom of a culture "is often enough mere senile dementia." (p. 365). Psychoanalysts may agree with LaBarre's unrestrained application of psychoanalytic interpretations to cultural evolution, but hardly any other group will.

The last chapter, "Three Minutes to Midnight," is concerned with the current scene. Militarism and political absolutism are conceived as imminent threats to continued cultural evolution; human speciation is now and has for long been cultural rather than organic.

Whatever one may think of specific details of *The Human Animal*, it should be said in its favor that LaBarre's position is openly stated throughout, even though it may be controversial. A good example is his conclusion that the hypothesis of the soul is a garment ill fitting modern man: it is poor physics, bad embryology, bad biology, poor psychology, and "a wholly inadequate anthropology." (p. 302).

The Human Animal, because the theme of the biological evolution of behavior runs through it from beginning to end, will probably appeal forcefully to those whose intellectual orientation is to biology.

Wayne University
Detroit, Michigan

FRANK E. HARTUNG

Teamwork in Research. Edited by GEORGE P. BUSH and LOWELL H. HATTERY. 191 pp. The American University Press, Washington, D. C., 1953. $4.00.

Interpretations of the term "human biology" vary. One definition, supported by the existence of monographs so labelled, is "an interdisciplinary study of man as a biological organism."* With behavior forming a link between the natural and social sciences, the boundary must remain open.

In any interdisciplinary area, team research represents the dominant mode of operation. For this very reason the present volume is of definite interest, even though the specific problems of team research in human biology are not considered in detail, and the case studies cited draw on applied physics, operations research, and the science of computation.

The volume is an outgrowth of the third Institute on the Administration of Scientific Research and Development, sponsored by the American University, the National Research Council, and the American Association for the Advancement of Science. It is a sequel to *Scientific Research: Its Administration and Organization* (American University Press, 1950).

The trend toward team research was accelerated by war-time projects. Some of these demanded a pooling of skills and knowledge which could only be provided by individuals with different scientific and technical specialization. The effectiveness of cooperative efforts in handling complex problems was amply demonstrated by such dramatic advancements as the development of the proximity fuse. At the same time, this *modus operandi* poses numerous problems not encountered by individual specialists working alone or with a few assistants on problems of limited scope.

The present volume is concerned with several aspects of team research. In addition to the case studies, noted above, it consists of 12 papers grouped under the headings of Organization for team work, Personnel factors, and Aids to teamwork. There is an introductory and concluding chapter by each of the two editors.

Research workers who are not expressly interested in administrative matters will still find the reading rewarding. Perhaps the "sideline" comments will be found most instructive. Do you not agree that *all* research is a type of production and as such must be planned, budgeted and scheduled (p. 25); that universities have been in the past and will continue to be the prime movers in the field of basic research (p. 39); that, in contrast, governmental agencies are likely to stress practical results and are not too anxious to wait around for a more basic understanding of a subject (p. 65); that the optimal size of a team is between

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* A. Keys, J. Brožek, A. Henschel, O. Mickelsen and H. L. Taylor, 1950, The Biology of Human Starvation, University of Minnesota Press.

4 and 10 (p. 66); that adequate communication is a key factor in maintaining an effective team (p. 74); that there is an optimum in the pressure exerted to get a job done and that the creative activity within the group goes down if the pressure is substantially increased or decreased (p. 77); that the primary goal of any research administration is to maintain environment conducive to good research (p. 105); that an important facet of the research director's job is to clarify and to keep clear the ultimate aim of the investigations, inviting every member of the team to participate to the limit of his capacities in reaching out towards the common goal (p. 136); that unless the individual workers and the team as a whole are kept properly oriented and inspired, the chances are great that the product will soon sink to a level of mediocrity (p. 143); that the spirit of an institution transcends its formal organization and that the organization chart represents merely a framework, with the real dynamic power lying in the individuals who make up the organization and in their motivation to work together to achieve recognized objectives?

In summary, as disciplines fragment due to ever-increasing specialization and as problems increase in complexity, the need for a coordinated cross-disciplinary approach increases, is the normal state, and is mandatory (p. 186). This applies directly and definitely to all of the larger problems of human biology.

University of Minnesota
Minneapolis, Minn.

JOSEF BROŽEK

The Psychological Variables in Human Cancer: A symposium. Edited by JOSEPH A. GENGERELLI and FRANK J. KIRKNER. 135 pp. University of California Press, Berkeley, 1954. $3.00.

It is no longer novel to hear claims that psychological factors are significant in the etiology of the progress of physical disorders. It is novel, however, to find physicians and psychologists joining in an all-day symposium on psychological factors in neoplastic disorders. Let it be pointed out immediately that no one connected with the symposium claimed that thoughts or feelings can cause cancer. They did claim, however, that mental activity can influence the progress of the disease. Should the symposium be summarized in one sentence, it would go something like this: If a patient is serene he will do better with his disease; if he is anxious, or otherwise agitated, his prognosis is poorer. According to the symposium, then, human cancer is a psychosomatic disorder, not in etiology, but in the course of the disease.

The symposium involved 6 reports with scheduled discussants for the first 5. M. Cutler "sang the theme song." It was he who claimed that, in his experience, patients who were "serene"—those who had faith in their God, their physician, themselves, or in any other factor—had a better chance for recovery.

Perhaps the most dramatic episode of the symposium was registered by the second participant, P. M. West. He described a patient who was explored for stomach carcinoma which was found to be nonresectable. Cancer cells were found in most of the stomach, the surrounding tissues, and even in the liver. The patient was discharged with the belief that his operation had been successful. Nine years later he was readmitted with a fatal heart disease. Autopsy showed *no* tumor cells. His wife said that "her husband had . . . had [no] stomach distress . . . and had been perfectly well until the day of the heart attack."

The remainder of Dr. West's report traced the history of his conclusion that psychological factors play a role in the course of cancer. He was the goad for the other reports of the symposium—in fact, the symposium itself.

F. W. Ellis, a colleague of Dr. West at the Veterans Administration Hospital at Long Beach, California, presented case summaries which tended to support the general theme of the symposium. Two reports represented doctoral dissertations by psychologists. E. U. Blumberg concluded that the Minnesota Multiphasic Personality Inventory and the Rorschach test, together, could separate patients with fast-growing and slow-growing cancer, and B. Klopfer, as a discussant, presented a convincing theoretical analysis of Blumberg's results.

T. L. Clemens sought to test the hypothesis that apparent hyperactivity of the sympathetic branch of the autonomic nervous system is prejudicial toward recovery from cancer. Specifically, he tested patients with slow and fast-growing cancer and found some significant differences in autonomic function. His results need verification, as do Blumberg's, but the conclusions of both are in harmony with the theme of the symposium. The concluding report, by the chief psychiatrist at the host hospital, J. S. L. Jacobs, was an erudite presentation of the concepts of host-resistance and host-acquiescence with an argument for the value of the latter in some psychosomatic disorders.

The reviewer believes that the symposium was ill-timed. It was held too soon. Nevertheless, the observations deserve attention and the conclusions reported in this symposium may be regarded as essentially valid. Apparently, cancer is not *just* an "organic" disease and there are ways of alleviating its destructiveness involving other tools than those of the radiologist and the surgeon.

M. A. WENGER

University of California
Los Angeles, California

Social and Psychological Factors Affecting Fertility, Volume 4. Edited by P. K. WHELPTON and CLYDE V. KISER. vi + 801-1086 pp. Milbank Memorial Fund, New York, 1954. $1.00.

Culture and Human Fertility. Edited by FRANK LORIMER. 510 pp. Unesco, Paris, 1954. $4.50.

Induced Abortion on Psychiatric Grounds. By MARTIN EKBLAD. 238 pp. Ejnar Munksgaard, Copenhagen. 1955.

Sexuelle Konstitution. By HELENE STOURZH-ANDERLE. ix + 262 pp. Wilhelm Maudrich, Vienna-Bonn, 1955. $6.25.

The first of these volumes, number 4 in the series of the same title, contains 7 further studies. Swain and Kiser examine the interrelationship of fertility, fertility planning, and ego-centered interest in children. Schacter and Kiser inquire into the fear of pregnancy and childbirth. Westoff, Hererra and Whelpton discuss the use, effectiveness, and acceptability of methods of fertility control. Westoff and Kiser make an empirical re-examination and intercorrelation of selected factors—marital happiness, feeling of personal adequacy, tendency to plan in general, and feeling of economic security. Kantner and Kiser examine the interrelation between fertility, fertility planning, and intergenerational social mobility. Riemer and Kiser report on economic tension and social mobility in relation to fertility planning and size of planned family. Finally, Kantner and Potter report on the relationship of family size in two successive generations.

Culture and Human Fertility is a study of the relation of cultural conditions to fertility in non-industrial and transitional societies. To this field of population studies it represents a major contribution. Notestein in the preface gives a succinct amount of the origin of the volume.

and Lorimer contributes a most stimulating and valuable section on general theory which will be of equal interest to cultural anthropologists as to human biologists. In part two Professor Fortes reports the results of a valuable field study in Ashanti, West Africa. Fortes makes much new information available and brings valuable evidence to the support of the theory of adolescent sterility. In part three K. A. Busia discusses some aspects of the relation of social conditions to human fertility in the Gold Coast. Richards and Reining report on fertility surveys in Buganda and Buhaya in 1952, and indicate something of the difficulties of obtaining reliable demographic information among nonliterate peoples. In part five Mortara reports on the Brazilian birth rate and the economic and social factors. There is a good index.

Scandinavia shelters one of the most civilized populations in the world. In Sweden there has been a law which enables women, who for psychological or other reasons would suffer from an unwanted pregnancy and its issue, to undergo an abortion. In the present monograph Dr. Martin Ekblad reports on a follow-up study of 479 women in whom abortions were induced on psychiatric grounds. His study is as exhaustive as such a study can be, and his conclusions are that on the whole the abortions were personally and socially beneficial, and he recommends, on very good grounds, that where sterilization is indicated it should more frequently be induced.

The last volume is the first in a new series entitled Wiener Beiträge zur Sexualforschung under the editorship of Dr. W. F. Brix. *Sexuelle Konstitution* is a popularly written work of a type which one associates with Vienna, the Blue Danube, and "Gemütlichkeit." The book is about the constitutional basis of sex, not a scientific work, but the reflections of the author on sex with especial reference to constitution, psychopathy, criminality, and genius, in which the data of science are used as the author chooses with a preternatural reliance on secondary sources. Most of the important work done outside German-speaking countries is largely neglected by the author. The facts are often questionable, and the author's opinions are usually debatable. This does not, however, prevent them from being both interesting and interestingly expressed.

ASHLEY MONTAGU

Princeton, New Jersey

Man in a Cold Environment. By ALAN C. BURTON and OTTO G. EDHOLM. xiv + 273 pp. Edward Arnold, London. 1955. $6.75.

The relationship between man and his environment is becoming more complex as the inhabited areas are rapidly expanding toward the poles and to zones well above and below the surface of the earth. Cold is common to much of this extended domain and it is urgent to increase our understanding of the impact of cold on man. A unique presentation and interpretation of the status of our knowledge of this subject by two well qualified authors is not only welcome and valuable for purposes of orientation but should stimulate further interest and work in this important field.

Several features of the book are outstanding: a consistent scheme for describing heat exchange is followed throughout; overall organization and chapter organization is excellent; and the many topical summaries reinforce points the authors wish to stress. Treated in turn are philosophy, physical concepts of heat exchange, physiological maintenance of the thermal steady state, impact of the environment on animals and man, consequences of acute and prolonged heat imbalance, and future problems for research. Selected pertinent literature relevant to these topics is critically presented, analyzed and discussed. Several un-numbered tables, 75 figures and illustrations and numerous equations support the text. Since the cut-off date for published literature was December 1951, workers in the field will note instances where data from subsequent experiments have modified interpretations and conclusions (for example, the recent work of Rodahl has indicated that diet is largely responsible for the higher basal metabolism in Eskimos). This, fortunately, is an indication of progress and not a criticism of the monograph.

The original purpose of the monograph was to make available the wartime military reports on man in the cold. This aim was modified "as the physiological content of importance was found to be small" in many of these reports. This comment is no doubt true but perhaps many of these reports contain "buried" information, which, if subjected to consolidated statistical analysis, would provide valuable information. Since an analysis of this type was beyond the scope of the present contribution, a thorough review of the wartime work still remains to be accomplished.

Stress Physiology
QM R and D Command
Natick, Mass.

R. E. BUSKIRK

Cold Injury. Third Conference. Edited by M. I. FERRER. 226 pp. Josiah Macy, Jr. Foundation, New York, 1955.

The third conference on cold injury was held at Fort Churchill, Manitoba, Canada, during the month of February 1954. Thus, the panel of participants was unequivocally close to the topic of mutual interest and discussion. Various workers presented their findings on pertinent problems asociated with cold exposure, including interrelationship of circulatory and metabolic factors, metabolic study of the Eskimo, comparison between Eskimo, Indian, and White males, fat distribution and respiratory quotient, diet and survival, and the roles of ascorbic acid and subcutaneous fat in the prevention of cold injury in man. Spirited criticism and discussion of each presentation took place. Supplementary data provided by discussants is included in the text for the reader's benefit. In addition, the reader benefits from critical evaluations of the papers. Frequently, however, he is confused by the lack of continuity of discussion. Unfortunately, summaries of pertinent findings are not included. This seems to make the present book, and in general, most books of this type, incomplete.

E. R. BUSKIRK

Stress Physiology
QM R and D Command
Natick, Mass.

Genetics and Metabolism. By ROBERT P. WAGNER and HERSCHEL K. MITCHELL. xi + 444 pp. John Wiley, New York, 1955. $7.50.

The statment E. B. Wilson made in 1896 that "... inheritance is the recurrence, in successive generations, of like forms of metabolism" has lost none of its validity. The book by Wagner and Mitchell is a highly successful attempt to assemble the data which support this concept. It is quite clear that hereditary factors control patterns of metabolism, but the *mechanisms* through which the control is exerted are still very incompletely understood. This book is perhaps the first to point up the problems which must be solved before we become acquainted with the genetic mechanisms of metabolic control and therefore provides the extremely valuable stimulation which generally comes from pioneering endeavors.

The authors provide a lucid introduction to genetics and a description of cell structure and function in the first two chapters. These are essential for the non-geneticist if the rest of the book is to fulfill its purpose. Fortunately, the authors also teach a good bit of chemistry in the subsequent chapters, which will be as helpful to geneticists as to all other non-chemists.

Most of our knowledge of the genetic control of metabolic patterns comes from studies with a mold (*Neurospora*), bacteria, fruit flies and mice. It might seem that these tiny forms of life are too distant relatives to provide anything of value to an understanding of human biology. However, the fundamental relationships between gene and enzyme are probably very similar for all forms of life as the Mendelian laws of heredity function in the same ways in both men and molds. There is very little in this book which is *not* fundamental to an understanding of the physiology of man.

An excellent chapter on cytoplasmic inheritance should convince the reader that the authors were not lost in their genes. They have a clear conception of the relative functions of cytoplasm and nucleus, and progress in research on human metabolism will proceed fastest if the relationship between nucleus and cytoplasm is kept in mind.

This book is not recommended as lunch reading but as a course of work for the serious research worker anywhere in the field of human biology.

University of Minnesota
Minneapolis, Minn.

SHELDON C. REED

An Introduction to Human Biochemical Genetics. By H. HARRIS. iv + 96 pp. Cambridge University Press, London and New York, 1953. $2.75.

The study of human biochemical genetics was initiated at the beginning of this century almost simultaneously with the rediscovery of the Mendelian rules for heredity. An English physician, Sir A. E. Garrod, was responsible for much of the early interest in human biochemical genetics. In the last decade the subject has flourished and Dr. Harris' book brings together the main advances since Garrod.

Although our knowledge of chemical variation in man is still very much in its infancy and is confined to a rather haphazard series of examples, the facts that have been discovered are of prime importance to the train of thought of the "human biologist."

This monograph is not only concerned with traits which are obviously the result of metabolic errors but also with differences in taste sensitivity to the thioureas. Even this group of genetic differences in the reaction of people to biochemicals may have some significance for health and survival. It has been apparent for some time that even the classical blood groups of Landsteiner can no longer be thought of simply in terms of genetic symbols. The blood group genes influence the specificities of mucoid materials in all the organs and body fluids. These genes have survival values which are of considerable magnitude, even though the selective value varies with the remainder of the genotype and the environment of each person.

Dr. Harris has succeeded admirably in reviewing the literature on biochemical genetics. Even more important is his capacity for exciting interest about research of the future. All sorts of unexpected discoveries result from almost any thorough study of the genetics *and* biochemistry of practically any human trait. Many of the readers of *Human Biology* will find themselves playing a part in this research eventually if they are not already involved in one way or another.

SHELDON C. REED

University of Minnesota
Minneapolis, Minn.

BOOK NOTICES

SCIENTIFIC METHOD IN PSYCHOLOGY. By Clarence W. Brown and Edwin E. Ghiselli. ix + 368 pp. McGraw-Hill, New York, 1955. $6.00. Like Caesar's Gaul, the volume is divided into three parts, starting with general ideas about the scientific method (with the control of psychological variables, and some facts and principles of psychological measurement added for good measure), continuing with steps in the application of scientific method (defining the problem, collecting the facts, analyzing and interpreting the data), and ending with some special problems of methodology (the physical testing situation, variables associated with the responding subject, quantification of behavior under conditions of laboratory experimentation, and some problems of field studies). A useful addition to psychological textbook literature.

FUNDAMENTALS OF ECOLOGY. By Eugene P. Odum. xii + 384 pp. W. B. Saunders, Philadelphia, 1953. $6.50. The book was intended to serve two purposes: as a college textbook and as a reference for those engaged in a variety of fields in which ecological principles are applied, including public health and welfare. There is a brief chapter on the more direct applications to human society, with emphasis on the interaction between the "natural" and the "cultural" aspects of human ecology.

MOTIVATION AND PERSONALITY. By A. H. Maslow. xiv + 411 pp. Harper, New York, 1954. $4.50. Historically, psychiatry and not experimental psychology, the study of emotionally sick and not of the happy and well-adjusted individuals provided the basis of the "scientific" picture of human nature. The author rejects such a portrait and calls for *positive* psychology, studying healthy human beings at their full height. The appendix on "Problems generated by a positive approach to psychology" might usefully serve as required reading for candidates choosing the topic for their Ph. D. thesis. A thoughtful, pioneering, provocative book.

THEORIES OF PERCEPTION AND THE CONCEPT OF STRUCTURE. By Floyd H. Allport. xxii + 709 pp. John Wiley, New York, 1955. $8.00. When a mature social psychologist embarks on a study of perception, a field heavy-laden with facts and theories, there are only two alternatives: the outcome will be either tripe or a significant, stimulating contribution. Happily, in this case, it is the latter. The objective of the labor was twofold: to survey and bring order into the modern psychological theories of perception, the process by which organisms obtain information about the world in which they live, and to outline the author's concept of structure, applied to human behavior and social action, and presented within the framework of a more general "theory of structuring of events." The implications for various fields of science, beyond the study of perception, are to be developed in a future volume or volumes.

Textbook of Biochemistry. 2nd edition. By Edward S. West and Wilbert R. Todd. xii + 1356 pp. The Macmillan Co., New York, 1955. $12.00. Within the span of a quarter century, biochemistry developed into a vastly complex science, with new techniques (such as the use of isotopic atoms to trace the chemical pathways of substances in the body) contributing to its accelerated rate of growth. The second edition continues the comprehensive coverage of the field, incorporating the principles of physical and organic chemistry. Implications of biochemistry, including nutrition, for medicine are considered. Expansion of the section on chemical body composition (p. 382) in the next edition may be useful. Similarly, the methods for the study of body composition *in vivo* seem to have earned the price of the admission ticket.

Advances in Experimental Caries Research. Edited by Reidar F. Sognnaes. ix + 236 pp. American Association for the Advancement of Science, Washington, D. C., 1955. $6.75. The monograph presents results of researches on the experimental production and prevention of tooth decay in laboratory animals. In view of the complexity of the subject (reflected in the participation of investigators representing anatomy, pathology, zoology, biochemistry, nutrition, and bacteriology as well as dentistry), the résumé on the effect of various agents tested in reference to experimental animal dental caries (with doubts cast on the adequacy of acidogenic theory of dental decay) and the editor's general summary will be found useful.

Kinships of Animals and Man: A textbook of animal biology. By Ann H. Morgan. viii + 839 pp. McGraw-Hill, New York, 1955. $6.75. A good undergraduate textbook of animal biology. While man is also considered, the material is predominantly zoological.

An Introduction to Human Anatomy. By Clyde Marshall and Edgar L. Lazier. xiii + 420 pp. W. B. Saunders, Philadelphia, 1955. $4.50. The fourth edition of an elementary text.

Experimental Design and Its Statistical Basis. By D. J. Finney. xi + 169 pp. The University of Chicago Press, Chicago, 1955. $4.50. An outline of the theory and practice of experimental design aiming to be intelligible to students and research workers in most fields of biology. It is not a textbook and not a cook book. Its principal purpose is to arouse the reader's "interest in a subject whose importance to good research practice is increasingly recognized."

Industrial Society: The Emergence of the Human Problems of Automation. By Georges Friedmann. 436 pp. The Free Press, Glencoe, Ill., 1955. $6.00. The subject matter is much the same as one finds in textbooks of industrial psychology. However, the presentation is fresh, smooth, and stimulating. Some of the European experiences in the field of industrial relations will be of special interest to the American reader. Rightly, the interdependence of the technological, physiological, psychological and sociological facets of industry is stressed. "In this rich field, the coexistence of different perspectives and levels has been recognized; each of them contains an aspect of reality and none of them reveals the whole of it." Industrial mechanization is reviewed as a great experiment in the history of civilization.

FROM CUSTODIAL TO THERAPEUTIC PATIENT CARE IN MENTAL HOSPITALS. By Milton Greenblatt, Richard H. York, and Esther L. Brown. vii + 497 pp. Russell Sage Foundation, New York, 1955. $5.00. The evaluation of new concepts and more humane and effective practices in the care and treatment of the mentally ill is presented in reference to three outstanding hospitals. What has been learned through study of the hospital social system and analysis of ward care and through direct experiment has wide application, both to the institutional treatment of mental disorders and the broader problems of mental health and disease.

LAS TREPANACIONES CRANEANAS EN EL PERÚ EN LA ÉPOCA PRE-HISPÁNICA. By Francisco Graña, Esteban D. Rocca, and Luis Graña R. 340 pp. Imprenta Santa Maria, Lima, 1954. (no price). While therapeutic neurosurgery is one of the most recent additions to scientific medicine, cranial trepanation is a surgical procedure with longest firmly established history. The authors examine in detail the development of cranial surgery in the territory of Peru during the long years from 3,000 B. C. to the 16th Century of our era. A review of earlier studies (1865-1951), description of the material, operative technique and instrumentation, ideas about the etiopathogenesis, and comment are presented in turn. Numerous illustrations.

THE HARVARD LIST OF BOOKS IN PSYCHOLOGY. Compiled and annotated by the psychologists in Harvard University. viii + 84 pp. Harvard University Press, Cambridge, 1955. (no price). 607 books are listed, with a brief evaluative comment, in 30 categories. A useful bibliography of contemporary psychology.

THE HUMAN MACHINE: Biological Science for the Armed Services. By Charles W. Shilling. xii + 292 pp. U. S. Naval Institute, Annapolis, 1955. $5.00. Originally designed for the Hygiene Department of the U. S. Naval Academy as the basis for instruction in biological science. Part One deals with the construction and operation of the human machine, Part Two, with problems of maintenance (including personal, community, military hygiene), Part Three, with man as a part of the war machine (including submarine and aviation medicine, and atomic, biological, and chemical warfare). A non-technical, readable presentation.

University of Minnesota
Minneapolis, Minnesota

JOSEF BROŽEK

INFORMATION FOR CONTRIBUTORS

Human Biology, a record of research. is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of 8½ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

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Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the proof has been returned to the press.

Human Biology

a record of research

VOLUME 28 FEBRUARY, 1956 NUMBER 1

CONTENTS

ESSAY ON A FUNDAMENTAL LAW OF LIFE: THE TIME-FACTOR (RELATIVITY) IN BIOLOGICAL PHENOMENA. *E. R. N. Grigg* 1

THE ABO BLOOD GROUPS AND THE SEX RATIO. *Bernice H. Cohen and Bentley Glass* 20

CRANIAL ALLOMETRY IN THE GREAT APES. *Eugene Giles* 43

RELATION BETWEEN HAIR COLOR AND METALS IN HUMAN HAIR. *Hideo Kikkawa* 59

FORCE ANALYSES OF HORIZONTAL TWO-HANDED PUSHES AND PULLS IN THE SAGITTAL PLANE. *George R. L. Gaughran and Wilfred Taylor Dempster* 67

BOOK REVIEWS 93

BOOK NOTICES 104

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Editor

GABRIEL W. LASKER

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BENTLEY GLASS WILLIAM W. HOWELLS

JAMES N. SPUHLER WILLIAM L. STRAUS, JR.

Review Editor

JOSEF BROŽEK

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This special issue, edited by Josef Brožek of the Laboratory of Physiological Hygiene, University of Minnesota, is devoted to the proceedings of the Conference on the Role of Body Measurements in the Evaluation of Human Nutrition, sponsored by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council, held at Harvard University, Cambridge, Massachusetts, June 17 and 18, 1955.

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INTRODUCTION

The appearance of nutritional anthropometry is a most welcome development for physical anthropologists. Anthropometry in its early days was devoted to the comparison of races in their skeletal dimensions; it almost seemed to wish, in a perfectly humane way, of course, that all of its subjects were skeletonized, as some of them were; and its techniques were designed to render as negligible as possible individual differences in fat and muscle. The result was that anthropologists got what they wanted: data on the skeleton only, squeezing out the rest of their subject. There was evolved an advanced and competent instrumental and statistical technique which eventually outstripped the data themselves. When racial comparisons had been more or less completed, and certain studies of growth and other kinds of variation made, there was a reduced scope for the technique. Obviously the neglected area from bone to skin awaited investigation, but this was slow in coming. The influence of genetics accented blood group and other physiological work; and constitutional anthropologists, largely following Sheldon, turned attention to consideration of all the constituents of physique, not the skeleton alone, though by means of a technique which is in its nature rather specialized.

With the arrival of broader problems of nutrition and of the analysis and variation of all the constituents of physique together, the traditional methods and approach of anthropometry find their natural extension. These problems will certainly benefit anthropological techniques as much as the techniques will benefit the studies, and their mutual development represents the kind of outlook in physical anthropology which was unceasingly encouraged by Professor Hooton. It was therefore particularly fitting that the Conference on Nutritional Anthropometry should have been held at Harvard.

W. W. Howells
Department of Anthropology
Harvard University

HUMAN BIOLOGY
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RECOMMENDATIONS CONCERNING BODY MEASUREMENTS FOR THE CHARACTERIZATION OF NUTRITIONAL STATUS

FOREWORD

THE Recommendations and the articles published below are the outcome of a meeting held on June 17 and 18, 1955, by the Committee on Nutritional Anthropometry of the Food and Nutrition Board of the National Research Council. The meeting, attended by 34 invited experts and observers in addition to members of the Committee, was held in Littauer Hall in Cambridge, Massachusetts, by courtesy of Professor W. W. Howells and the Administration of Harvard University.

This was the final official activity of the committee which was established in May, 1951, in recognition of the situation indicated in a report to the Board (Minutes, Vol. 9, p. 28, May 1949):

"The need for this committee arises from the fact that the evaluation of the nutritional status of man with regard to emaciation, obesity, growth, skeletal and muscular development is a major neglected area of human nutrition. Such evaluation must depend primarily on physical measurement of the body and comparisons with suitable standards for selected items of measurement. There are at present no well-defined uniform methods or properly characterized standards for these purposes. Common methods of physical anthropology are devised with a view to different problems. Common clinical methods are extremely crude and relatively subjective.

"For the development of this area, it is necessary to use facts and expert knowledge from several fields which do not ordinarily have contact with each other. Among these would be nutrition, physical anthropology, pediatrics, physiology, actuarial science, anatomy, physiological hygiene, and general statistics. There are at present neither national nor international organizations to consider these problems or to assemble experts from the several fields which can contribute.

"The American Medical Association, the Food and Agriculture Organization, and the World Health Organization, in addition to the Food and Nutrition Board, have recognized the need for some organization to consider these problems. There seems to be general agreement that the National Research Council would be a suitable focus for such activities and that, within the Council, the Board would be the proper sponsoring agency."

Impetus to the establishment of the Committee was given by the Second Session of the Joint FAO/WHO Expert Committee on Nutrition, in Rome, April, 1951, which stressed the relationship between bodily dimensions and nutrition and pointed to the need for anthropometric data utilizing agreed methods and standards (World Health Organization Tech. Rept. Ser. 1951, No. 44, pp. 63-64). The Fourth Session of the Joint FAO/WHO Committee again emphasized these points (W. H. O. Tech. Rept. Ser. 1955, No. 87, p. 44) and recommended "That efforts be made in the near future to assemble a study group or expert committee to consider and to report on these questions of methods, standardization of procedures and reporting, the planning of surveys, and the provision of norms, and on the whole problem of the application of anthropometry to nutritional evaluation."

At the Harvard meeting all in attendance were "co-opted" for participation in the formulation, drafting, and discussion of the Recommendations. Subsequent to the sessions at Harvard, an edited draft of the Recommendations was sent to each of the participants and to members of the Food and Nutrition Board for comment and emendation. The final draft published here embodies the responses.

Acknowledgment should be made of the contributions to the work of the Committee by Committee members who served until 1954: Drs. Harold C. Stuart of Harvard University, Grace A. Goldsmith of Tulane University, Louis I. Dublin, formerly of the Metropolitan Life Insurance Company, N. Y., and M. W. Krogman, of the University of Pennsylvania. Important contributions were made by correspondence by Drs. J. M. Tanner, St. Thomas's Hospital, London, and G. M. Morant, R. A. F. Institute of Aviation Medicine, Farnborough, England.

Throughout the life of the Committee Dr. Josef Brožek acted as Secretary and he also edited the Recommendations and papers published here. The participants at the Harvard Meeting are listed below. Their concurrence with the Recommendations is on a personal basis and does not necessarily reflect the official views of the organizations they represent.

Participants

S. Abraham (Heart Division, Control Program, U. S. P. H. S., Washington, D. C.).

W. R. Aykroyd (Nutrition Division, Food and Agriculture Organization, Rome).

Paul Baker (Q. M. Research and Development Center, U. S. Army. Natick, Mass.).

David E. Bass (Q. M. Research and Development Center, U. S. Army, Natick, Mass.).

J. M. Bengoa (Section on Nutrition, World Health Organization, Geneva).

J. H. Browe (Bureau of Nutrition, New York State Dept. of Health, Albany, N. Y.).

Josef Brožek (University of Minnesota, Minneapolis, Minn., COMMITTEE ON NUTRITIONAL ANTHROPOMETRY).

E. R. Buskirk (Q. M. Research and Development Center, U. S. Army, Natick, Mass.).

Callie M. Coons (U. S. Department of Agriculture, Washington, D. C.).

R. F. A. Dean (World Health Organization, Makerere Medical College, Kampala, Uganda).

E. Demaeyer (IRSAC, D. S. Bukavu, Belgian Congo).

S. M. Garn (Fels Research Institute, Antioch College, COMMITTEE ON NUTRITIONAL ANTHROPOMETRY).

William Walter Greulich (Department of Anatomy, Stanford University, California).

M. I. Grossman (Medical Nutrition Laboratory, Office of the Surgeon

General, U. S. Army, Denver, Colorado. COMMITTEE ON NUTRITIONAL ANTHROPOMETRY).

W. W. Howells (Dept. of Physical Anthropology, Harvard University, Cambridge, Mass.).

E. E. Hunt (Forsyth Dental Infirmary for Children, Boston, Mass.).

Ancel Keys (University of Minnesota, Minneapolis, Minn., COMMITTEE ON NUTRITIONAL ANTHROPOMETRY).

Werner Kornfeld (Department of Pediatrics, New York Medical College, N. Y.).

H. H. Marks (Metropolitan Life Insurance Company, New York, N. Y.).

Jean Mayer (Food and Agriculture Organization, Harvard University, Boston, Mass.).

O. Mickelsen (National Institute of Arthritis and Metabolic Diseases, Bethesda, Md.).

R. W. Newman (Q. M. Research and Development Center, U. S. Army, Natick, Mass.).

G. F. Ogilvie (Nutrition Division, Dept. of National Health and Welfare, Ottawa, Canada).

Margaret A. Ohlson (Michigan State University, East Lansing, Mich.).

L. B. Pett (Department of National Health and Welfare, Ottawa, Canada).

Robert B. Reed (Harvard University, Boston, Mass.).

Robert Ryer, III (Medical Services Liaison Officer, Q. M. Food and Container Institute, Chicago, Ill.).

Nevin Scrimshaw (Pan American Sanitary Bureau, World Health Organization, Guatemala City, Guatemala).

J. Senecal (World Health Organization, Dakar, French West Africa).

J. C. Sibigtroth (New York Life Insurance Co., New York, N. Y.).

William Siri (Division of Medical Physics, University of California, Berkeley, California).

Mildred Trotter (Department of Anatomy, Washington University, St. Louis, Mo.).

Isabelle Valadian (Harvard University, Boston, Mass.).

Jean M. Vasey (St. Thomas's Hospital, London, England).

L. Verhoestraete (Pan American Sanitary Bureau, World Health Organization, Washington, D. C.).

Robert White (Q. M. Research and Development Center, U. S. Army, Natick, Mass.),

ANCEL KEYS, *Chairman*

GENERAL CONSIDERATIONS

Body measurements and nutritional status

The growth, weight and composition of the body depend, in part, on the supply of nutrients and may serve as a useful, though limited, criterion of one aspect of nutritional status. For individuals of a given sex and age, body weight must be evaluated with reference to skeletal size, taking into account body height and also the width of the skeletal framework. This yields an estimate of the degree of underweight or overweight of the individual. In order to properly interpret the biological significance of body weight, data must be obtained for the approximate analysis of body weight in terms of body composition. The variable showing largest individual differences is body fat. While more complex methods are available for research, measurements of the thickness of subcutaneous fat provide a valuable measure of leanness-fatness in field work and in the physician's office.

The present recommendations are concerned primarily with adults. Nevertheless, measurements considered useful in children are listed. The problems of evaluating nutritional status in children are more complex than in adults and include rates of growth and effects of sexual maturation. These matters will not be discussed in detail here but should be at least mentioned since they are important for the interpretation of bodily dimensions as criteria of nutritional status.

In order that data obtained by different observers may be comparable, the measurements should be made in a standard manner. The apparent simplicity of the measurements is deceiving. The calibration of instruments should be checked periodically.

It should be realized that anthropometric data provide only a description of man's physique. The evaluation of biological significance of the individual differences in the rates of growth, adult body size and composition must be made in reference to such criteria as performance capacity, morbidity, and mortality.

Sampling

In surveys of whole populations as well as in surveys of specific groups (*e.g.* old people, pre-school children, etc.), one should strive for results that are representative, that is, results that are free from sampling bias with respect to the characteristic studied. Special skills are often required in sampling, and it is recommended that expert statistical advice be sought early by any group planning nutritional or anthropometric studies.

The method of sampling must take into account occupational, social and cultural characteristics of the area to be surveyed. For populations with a complex social structure, it is desirable that stratified samples be devised that reflect the composition of the population by sex, age, economic status, ethnic origin, occupation, and other factors pertient to the particular study. In less complex societies, the sampling plan would be less complicated but nevertheless crucial to the success of the study. In some circumstances it may be expedient to use the family or household as the sampling unit. Pilot studies are advisable before engaging in a mass survey.

After the sampling procedure has been devised, every effort should be made to obtain data for the entire sample. When this is not feasible, adequate information should be obtained about non-participants in order to estimate the nature and extent of the bias in the sample surveyed.

The nature of the population surveyed should always be clearly stated; some types of surveys, in particular, will be concerned with the “general” or “presumably healthy” population. Since concepts of this nature vary greatly, specific exclusions should be set forth in detail. Such exclusions should be based on, and explained on the basis of: 1) the frequency of prevalent disease states in the population or 2) specific recording of disease states present in individual cases included in the survey.

Selection of measurements

The principal aim of the application of body measurements in nutritional research and appraisal is: 1) to arrive at a relative weight of an individual, obtained as the ratio of the actual to the “standard” weight and 2) to appraise the relative fat content of the individual. Thus weight, height and a measurement of subcutaneous fat are the irreducible basic data.

In the subsequent sections recommendations are made for selection of additional measurements defining more satisfactorily the skeletal framework and the stores of subcutaneous fat. These are considered as minimal measurements for surveys. Other measurements may be useful for special purposes. When additional measurements are made, a detailed, clear description should be provided so that other investigators can reconstruct the actual procedure used by a given investigator.

Recording

The original records are the ultimate source of all information and should be made with care and accuracy. Whatever corrections are to be made, *e.g.* for the amount of clothing worn by the subject, should be made at the time of recording the weight and should be specifically indicated on the record. Preferably, the body weight should be *recorded* as nude weight and measured with minimal clothing. Samples of the weight of clothes worn should be made at intervals if weighing is done including clothes.

The precision of making and recording the measurements will vary with the purpose and circumstances under which the measurements are made. In surveys and in medical practice involving adults, readings of height to the nearest centimeter (or quarter-inch), weight to the nearest half-kilogram (or pound), and skinfolds to the nearest half-millimeter (or 1/32 inch) are adequate. In the case of children the accuracy of recording the measurements should be increased (perhaps doubled).

Ages reported by the subjects are notoriously unreliable. Every effort should be made to obtain correct ages. The day, month and year of birth or at least the month and year should be recorded. The actual age can be computed later by a clerk. In adults ages, in years, should be computed to the nearest birthday. In children year and the nearest month should be recorded.

Reporting

Preferably, the measurements should be made and reported in the metric system, in centimeters and kilograms. In countries using the English system, the data for use by laymen may be reported also in inches and pounds. As a rule, this should be an additional, not alternative, method of reporting and its usefulness would depend on the uses being made of the data.

In reporting group data, original distributions should be presented together with the descriptive statistics (means, standard deviations, etc). This is particularly essential for variables with skewed distributions for which percentiles rather than ranges based on the standard deviation (mean ± 1SD and ± 2SD) must be used. The percentiles to be used will again depend on the purpose of the norms. When gross classification is desired the 5th, 50th (median) and 95th percentiles are useful. At other times the use of quintiles (the 20, 40, 60, and 80 percentiles) is preferable. Finally, percentiles corresponding to the limits obtained for normally distributed variates (M ± SD) may be useful in some situations.

In grouping adult individuals according to age it is useful for many purposes to use a 5-year interval, preferably coinciding with the decades (25 to 29, 30 to 34, etc.). The age divisions for children are dealt with in a later section. In view of continued growth in height, at least in some populations, it is desirable to use groupings of no more than one year of age for ages below 25 years.

BODY MEASUREMENTS ON ADULTS

In different contexts—in the physician's office, in a field survey, in the laboratory—different sets of data may be utilized for the characterization of nutritional status (nutriture) with reference to body size and composition. Under emeregency conditions one may have to be satisfied simply with measurements of height and weight.

The bony dimensions are useful primarily in arriving at the individual's "standard" or "reference" body weight. A second class of measurements characterizes the individual's leanness-fatness. A third set of measurements serves to evaluate the development of musculature.

A. *Body weight* should be reported as in the nude, with an appropriate correction for clothing worn. This correction should be made at the time of measurement. The estimate should be checked from time to time by actually weighing the clothes, if standard garments are not used. Personal ornaments and accessories should be removed. It is recommended that body weight be included in every anthropometric study of human nutriture.

B. *Body dimensions*

1. *Stature* (standing height), defined as the distance from the sole of the feet to the top of the head, should be measured always without shoes. In case of necessity, the contribution of the shoes should be estimated and deducted at the time of the measurement.

Preferably, the subjects should be barefooted or in stocking feet, standing erect, with the heels and scapulae in contact with the wall or other flat vertical surface. The head should be held so that the line of sight is horizontal. The height should be determined by lowering a rectangular wooden object or other suitable guide, remaining in contact with the vertical measuring scale, until it makes firm contact with the scalp.

In patients who cannot readily stand, recumbent body length should be determined. For this purpose, a rigid board such as ¼″ plywood may be slipped under the patient's body, using a right-angled foot support for bringing the feet into position. If the two measurements are to be used as reference, allowance should be made for the fact that a person's recumbent length is somewhat greater than his stature. The measurement of stature or body length should be included in all assessments of human nutriture.

2. *Sitting height.* At times it may be desirable to have an indication of the proportion of the total height represented by the trunk and legs. Two measures have been used for this purpose, the sitting height and the cristal height. The relative merit of the two measurements (or the importance of the vertical partitioning of body height) is not clearly established at present. It may be noted that large fluctuations in individual body weight have surprisingly negligible effect on the sitting height.

The measurement is taken with the subject seated on a firm stool with a horizontal surface. The knees are flexed, the trunk in contact with the wall at both the scapular and sacral region. The position of the head is the same as in the measurement of standing height. The sitting height is the distance from the top surface of the stool to the top of the head.

The measurement is of secondary importance.

3. *Iliocristal height* is obtained, with the subject standing erect, as the distance from the sole of the feet to the highest point of the ilium. Adequate pressure should be exerted on the contact surface in order to minimize the effects of subcutaneous fat which may overlie the crest of the ilium. Care should be taken to maintain the hips horizontal.

This measurement is of secondary importance.

4. *Bicristal (biiliac) diameter.* The width of the pelvic girdle is obtained as the greatest distance between the lateral margins of the iliac crests. When necessary, strong pressure should be exerted on the contact surface of the calipers in order to minimize the amount of soft tissue which would otherwise be included in this measurement.

As a good measure of the laterality of the skeletal frame, this measurement is recommended as a standard item in the minimal set of anthropometric measurements. It should be used, together with stature (and additional measures of skeletal size, if available) in the estimation of the individual's standard body weight.

5. *Biacromial diameter.* This measure of the width of the shoulder girdle is determined as the distance between the most lateral margins of the acromion process of the scapulae. The subject stands erect but with shoulders relaxed.

Biacromial diameter is the second best measure of the laterality of the bony framework but it requires special care as far as the posture of the subject is concerned in order to avoid sizeable errors.

C. *Adipose tissue.* In order to interpret intelligently the biological significance of a departure of the actual weight from a standard body weight, it is necessary to estimate the relative contribution of the adipose tissue, serving as a true measure of obesity, and of musculature. Since a large amount of adipose tissue is located under the skin, the individual's leanness-fatness may be estimated by measuring the thickness of skinfolds. For purposes of order and economy, it is necessary to agree on the pressure to be exerted by the skinfold calipers and on the sites at which the skinfolds are to be measured. It has been a general experience that a pressure of about 10 gm/mm^2 is preferable to very low or very high pressures. It is recommended that this pressure be used by all investigators, irrespective of the design of the skinfold caliper. A useful size of the contact surface of the caliper lies in the neighborhood of from 20 to 40 mm^2, and depends in part on the shape of the contact surface. The skin should be lifted by grasping firmly a fold between the thumb and forefinger at about a distance of 1 cm from the site at which the skinfold is to be measured.

At present, there is a fairly unanimous agreement on the value of two sites: upper arm and scapula.

1. *Upper arm skinfold.* This site is readily accessible in individuals of both sexes and should be measured in all studies of leanness-fatness. The skinfold is located at the back of the right upper arm (over the triceps), at the level midway between the tip of the acromial process of the scapula and the tip of the elbow. The level is located with the forearm flexed at 90°. In making the skinfold

measurement, the arm should hang down freely. The skinfold is lifted parallel to the long axis of the arm.

2. *Scapular skinfold.* The skinfold measured below the tip of the right scapula provides a good characterization of the individual's overall fatness. The thickness of the subcutaneous adipose tissue is fairly homogeneous in this area and small differences in locating the site are less important than in the arm or abdominal region or chest. The scapular site should be measured whenever feasible.

D. *Muscular tissue.* Where the required facilities are available, the muscular development of an individual is best characterized in terms of the breadths of the muscular segments of soft-tissue X-rays of the limbs. Where direct anthropometric measurements must be used, the muscular development can be estimated from the limb circumferences, provided that the thickness of the subcutaneous layer is determined at the same time and, preferably, at the same level.

1. *Upper arm circumference* should be taken with the arm hanging freely, at a right angle to the long axis of arm, and at the same level as the arm skinfold measurement. The tape should be applied lightly to the skin, without deforming its contour.

BODY MEASUREMENTS ON CHILDREN

The measurements indicated here fall short of adequacy for research. They are intended primarily for use in the field. It is assumed that field workers will be aware of the qualitative (clinical) signs of nutritional debility and hypovitaminosis, that reasonable care will be taken in making the measurements, and that local practices likely to alter any measurement or combination of measurements will be recorded.

It may be useful to emphasize that not only the final stature but also the *pattern* of development (rates of growth, appearance of ossification centers) is under genetic control. Nutrition determines the extent to which the genetic potentials are achieved. During the period of growth it is more important to compare the child's weight and body dimensions with the measurements made previously on the same child than to relate the measurements to crossectional norms established for a given age.

Not all suggested measurements are equally practicable or equally informative at all ages from birth to maturity. Therefore 5 age levels are given, with a separate listing of measurements in each.

Ranking of measurements

The suggested measurements are ranked from A to E as follows:

A. Minimum list for emergency conditions
B. Should be added for survey work, except in emergencies
C. Desirable for survey work, still require little equipment
D. Desirable, but require equipment less readily available
E. Desirable, but rarely practicable in the field.

Informative value of measurements

Length measurements are concerned with: 1) total body length and 2), when crown-rump or sitting height are included, the relative contribution of trunk and legs.

Weight indicates gross body size (bulk) and gives a rough approximation of body volume.

Body circumferences and diameters indicate laterality of build, and (in early infancy) developmental status.

Leg and arm circumferences, as well as the body circumferences, indicate extent of development of the soft tissues, fat and muscle.

"Skin-folds" (*i.e.* folds of skin plus subcutaneous tissue) indicate the thickness of the subcutaneous fat, and help to differentiate fat from muscle.

Measurement by age level

At birth

A. Length (crown-heel maximum), stem length (crown-rump maximum), weight (cord drained).
B. Circumference$_1$ (head maximum), circumference$_2$ (chest maximum, mid-inspiration).
C. Diameter$_1$ (bicristal).

10 days to 1 month

A. Length, stem length, weight
B. Circumference$_1$, circumference$_2$
C. Diameter$_1$
D. Skinfold over the triceps, below scapula and on chest (along the midaxillary line at the level midway between nipples and umbilicus).

3, 6, 9 months

A. As above
B. Circumference$_{1,2}$ plus circumference$_{3,4}$ (arm and calf)
C. As above
D. As above
E. Postero-anterior X-ray film of the hand and wrist. It should include the terminal phalanges as well as the distal ends of the radius and the ulna.

1-6 years

A. Length, stem length, weight, standing length
B. As above, eliminating head circumference at 3 years
C. Diameter$_1$, diameter$_2$ (biacromial)
D. As above
E. As above

7-10 + years

A. Standing height, sitting height, weight
B. Chest, arm and calf circumferences
C. As above
D. As above
E. As above

Note: in this age level overt signs of sexual maturation or their absence should be systematically noted, since implications of all dimensions differ, for constant age, according to maturation status.

PHYSIQUE AND NUTRITIONAL STATUS OF ADULT MEN *

BY JOSEF BROŽEK

Laboratory of Physiological Hygiene, School of Public Health, University of Minnesota, Minneapolis, Minnesota

INTRODUCTION

MAN's physique is a complex phenomenon and its characterization will depend, in a large measure, on the investigator's purpose. In this presentation we are concerned with physique in relation to nutrition (*cf.* Brožek, '53). To narrow the subject matter still further, we shall limit our attention primarily to the adult man. While "maturity," roughly corresponding to the age range from 20 to 60 years, is not a static period (Brožek, '52), the average changes in body size and composition are much less rapid and dramatic than during childhood and adolescence (Shuttleworth, '51). Some aspects of development, such as the skeletal age assessed from x-ray films of the extremities (Greulich and Pyle, '50) are by now a closed chapter. The relationship between diet and age changes in the density of bones—estimated in the living from optical density (Mack, Brown and Trapp, '49), or, in the anatomist's workshop, in terms of the ratio of calcium in a bone to its volume—are not without interest. Nevertheless, the concern of the physical anthropologist working as a member of a nutritional team is directed principally to the soft parts of the body—the skeletal musculature and, in particular, the adipose tissue.

In the animal kingdom the role of accumulated fat as nutritional reserves is clearcut, whether it is generalized or sharply localized (as in the case of the humps in Arabian and Bactrian camels or the fat-tailed and fat-rumped sheep of Africa and Asia). It is not certain that the steatopygia of the Hottentot of Southern Africa does not belong to the same type of adaptation to a precarious food supply. However this may be, a comparison of the size and composition of the tail of desert sheep, enlarged with fat after the rains and plentiful food supply, and devoid of fat after drought (see Wright, '54, especially Fig. 5.20) tells eloquently the story of the importance of fat reserves as a crucial facet of nutritional status (nutriture), with sheer survival as the acid test of the value of the fat depots to the organism. When we come to man, cultural factors complicate the matter in several ways.

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The situation in which survival depends, in an important measure, on the portable bank of stored chemical energy are today infrequent, even though the specter of concentration camps and famished cities and whole regions is still hovering over us. The optimal size of the fat stores at different age levels is not known at the present time with the desired precision. Nevertheless, there is no doubt that the size of the fat depots, other things being equal, is a measure of the caloric balance accumulated over a period of time and thus an important aspect of nutritional status.

The methods and the attained precision of the evaluation of somatic espects of nutriture will vary with technical facilities, and it is necessary to differentiate clearly between tools applicable to emergency situations, detailed field surveys, and systematic laboratory research. The extremes are represented by gauging deterioration of nutritional status from changes in gross body weight of a population under conditions of severe dietary stress, on the one hand, and a detailed quantitative study of changes in the amount and distribution of soft tissues, in body fluids and in mineral density of bones, on the other hand (*cf.* Keys *et al.*, '50). Here we are concerned primarily with the simpler body measurements that can be obtained in the "field." The principles and techniques of the densitometric and hydrometric analysis of body composition were presented elsewhere (Keys and Brožek, '53, and Brožek, '54, with citation of the literature).

WEIGHT-HEIGHT INDEXES

The ratio of weight (W) to height (H) may serve as a first and very rough estimate of the amount of soft tissues in relation to the size of the skeleton. A variety of indexes relating weight and height have been proposed (*cf.* McCloy, '36, p. 14, Krogman, '41, especially p. 5 ff.), from simple W/H to ratios involving $\sqrt[3]{W}$. No attempt will be made here to analyze in detail the merits of the different forms of the weight-height index.

At a given height, the simple ratio of weight to height (kg/cm) provides an adequate measure of body bulk in relation to body length. The difficulties begin when one is to compare individuals of different height. More importantly, weight-height indexes share the basic limitations of all procedures which consider only the height as the reference point, neglecting the vertical proportions of the body, the lateral dimensions, and the need to take into account more directly the size of the skeletal musculature.

The problem of units ("dimensions") that may be legitimately related in the form of an index is readily solved by using relative weight, *i. e.* the actual weight expressed as a percentage of a standard weight. But what constitutes a meaningful standard?

ESTIMATION OF STANDARD WEIGHT

The "standard" weight has been defined, as a rule, as the average weight of individuals of same sex, age, and height. In the United States the basic tables of standard weight, so defined, were published in 1912 (Association of Life Insurance Medical Directors, '12) and reprinted many times, with or without essentially arbitrary corrections for the weight of shoes and clothes worn by the life insurance applicants on whom the data were based.

Comparisons with fairly recent data obtained on samples of personnel of the Armed Forces (Keys and Brožek, '53, p. 253) justify the conclusion that, by and large, the 1912 standards may be used as an approximately valid reference point in terms of which individuals in the U. S. and populations throughout the world may be compared. This is not to say that a systematic survey of the current weight status of the American population is not desirable. The excellent job done by the Canadians in this field (*cf.* Pett, '55) may serve as example of a carefully planned and well executed anthropometric survey of nutritional status. Clearly, such an undertaking appears to be the responsibility of public health authorities. Interests of the insurance industry are likely to remain limited to their patrons and to conditions under which routine medical examinations of life insurance applicants are made (*cf.* Lew, '54).

An inherent limitation of the height-weight tables is that the effect of variations in "body build" is not considered. In regard to the skeletal framework, both the vertical partitioning of the body into head plus trunk versus legs and the consideration of the lateral bony dimensions would appear relevant.

Several authors (*cf.* McCloy, '36, '38, Pryor, '40, Turner '43, Cureton, '47) have considered lateral dimensions of the skeletal framework and of limb bones in arriving at an estimate of standard weight. For the present purposes, the available literature is limited either in the selection of measurements or the character (particularly the age) of the samples or both. The importance of the vertical partitioning of the body has not been adequately examined. In some studies the lateral dimensions, especially the width of the chest, included also the subcutaneous adipose tissue, thus confusing the issue. Most of the samples were limited to young men and women (college students) and to children.

Comparison of an individual's actual weight with the weight predicted from bony measurements yields an estimate of the relative development of soft tissues. This value is of interest as a gross measure of the somatic aspect of "nutritional status." When the characterization of relative adiposity is the principal concern, the weight standards must consider both the skeletal size and the muscular development. The deviations from such a standard represent a continuum which is a good deal closer to leanness-fatness than is the case when only the bony dimensions are taken into account.

The relationship between body weight, anthropometric variables, and age were examined statistically in a group of 238 Minneapolis firemen, with the fire stations selected at random and all members at each station included in the examination. The means and standard deviations are given in table 1. The age range was 25 to 63 years, with the bulk of the sample in the decades 30 to 39 ($N = 76$) and 40 to 49 ($N = 103$). Firemen are of biomedical interest on several acounts. Most importantly, perhaps, they represent an occupational group that can be readily identified and described in terms of the mode of life, and can serve in cross-cultural population studies such as have been carried out on cooperative basis in Italy and Sweden (*cf.* Keys, Fidanza and Keys, '55).

The body measurements included standing height, as a measure of the total body length, and cristal height, as an indicator of the vertical partitioning of the body into trunk plus head versus "leg length." The lateral dimensions of the skeletal framework are represented by the bicristal and the biacromial diameters. The thickness of the limb bones is sampled in the form of the biepicondylar width of the humerus. The diameter (D) of the upper arm, corrected for subcutaneus fat, serves as a criterion of muscularity. It was calculated from the arm circumference (C), measured mid-way between acromion and olecranon, with arm relaxed, and the skinfold (S), measured at the same level on the back of the upper arm ($D = C/\pi - S$). Clearly, the number of measurements could be substantially increased, especially as far as criteria of muscularity are concerned. However, the practical demands for economy in field work served as an effective check on mensurational enthusiasm. Also, if the initial choice of variables is a happy one, in multiple regression equations the returns from increasing the number of predictors diminishes rather rapidly.

TABLE 1

Basic anthropometric data on 238 Minneapolis firemen

VARIABLE	SYMBOL	MEAN	S. D.
Weight, kg	Y	81.64	9.77
Height, cm	X_1	176.80	5.82
Cristal height, cm	X_2	108.94	4.81
Bicristal diameter, cm	X_3	29.43	1.53
Biacromial diameter, cm	X_4	39.94	1.90
Biepicondylar diameter of humerus, cm	X_5	7.14	0.43
Upper arm (muscle + bone) diameter, cm	X_6	9.07	0.65
Age, years	X_7	41.6	9.1

The first-order correlations are given in table 2. The multiple regression equation for estimating standard weight from bony measurements and age is given in table 3. The coefficient of multiple correlation $R = 0.6487$. Using all the 7 independent variables, we obtain the prediction equation given in table 4. When the significance of the beta coefficients in the multiple regression is tested statistically (table 5), it becomes apparent that the contribution of cristal height is negligible and its elimination (see Johnson, '49, especially p. 339) does not affect the coefficient of multiple correlation ($R = 0.772$). The beta coefficient for the biepicondylar diameter of the humerus does not reach the 5% level of significance, either when all 7 independent variables are considered or when the cristal height is eliminated. The prediction equation based

TABLE 2

Interrelations between anthropometric data on 238 Minneapolis firemen

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Y Weight	.4765	.4304	.4918	.4095	.5082	.5899	.1213
X_1 Height		.8911	.5241	.4154	.4067	.2138	—.2094
X_2 Cr. height			.5166	.4138	.3830	.1493	—.1469
X_3 Bicr. diam.				.2882	.4710	.1585	.2370
X_4 Biacr. diam.					.3056	.2355	—.1625
X_5 Biepic. diam.						.3756	.1650
X_6 Arm. diam.							—.0984
X_7 Age							

TABLE 3

Multiple regression equation for predicting body weight ($\hat{Y}$) from bony measurements (X_1 to X_5) and age (X_7)

$$\begin{aligned}\hat{Y} = &+0.532\,X_1\\ &-0.220\,X_2\\ &+1.088\,X_3\\ &+1.114\,X_4\\ &+5.772\,X_5\\ &+0.134\,X_7\\ &-111.704\end{aligned}$$

TABLE 4

Prediction equation for body weight ($\hat{Y}$), with 7 independent variables

$$\begin{aligned}\hat{Y} = &+0.379\,X_1\\ &+0.003\,X_2\\ &+1.085\,X_3\\ &+0.837\,X_4\\ &+1.836\,X_5\\ &+6.996\,X_6\\ &+0.202\,X_7\\ &-135.995\end{aligned}$$

on standing height, bicristal and biacromial diameter, upper arm diameter calculated from the arm circumference and corrected for subcutaneous fat, and age is given in table 6. As indicated in table 7, beta

TABLE 5

t-tests of the statistical significance of the beta coefficient in multiple regression equation with 7 independent variables

VARIABLE	t
X_1, Height	2.295*
X_2, Cristal Height	0.015
X_3, Bicristal diam.	3.015**
X_4, Biacromial diam.	3.391***
X_5, Biepicond. diam. of humerus	1.525
X_6, Upper arm diam.	9.985***
X_7, Age	3.828***

Levels of significance: * $t_{0.05} = 1.960$; ** $t_{0.01} = 2.576$; *** $t_{0.001} = 3.291$.

TABLE 6

Prediction equation for body weight ($\hat{Y}$) after the elimination of X_2 (cristal height) and X_5 (biepicondylar diameter of the humerus)

$$\begin{aligned}\hat{Y} = &+0.411\,X_1\\ &+1.204\,X_3\\ &+0.885\,X_4\\ &+7.342\,X_6\\ &+0.220\,X_7\\ &-137.510\end{aligned}$$

TABLE 7

t-tests of statistical significance of the beta coefficients in multiple regression equation with 5 independent variables

VARIABLE	t
X_1, Height	4.374
X_3, Bicristal diameter	3.421
X_4, Biacromial diameter	3.619
X_6, Upper arm diameter	11.109
X_7, Age	4.252

For comparison, $t_{0.001} = 3.291$

coefficients of all 5 variables are statistically significant beyond the 0.1% level with the upper arm diameter, as a measure of muscular (and bony) development, standing out as the variable with the highest t-ratio.

SUBCUTANEOUS FAT

Deviations from the weight standard, defined above, may be interpreted as "purer" measures of adiposity than when skeletal width and muscularity are not considered in arriving at the standard (reference) weight.

The characterization of the individual's relative leanness-fatness may be obtained, more directly and in still more "pure" terms, on the basis of the depth of the *tela subcutanea*. It is well known that a large fraction of the total amount of adipose tissue is contained in the subcutaneous fat depot which can be characterized quantitatively by measuring the thickness of the skinfolds by calipers or by noting the layer of skin plus subcutaneous tissue in soft-tissue roentgenograms (Reynolds, '51). At present only the use of calipers comes into consideration for extensive field work, although the development of portable x-ray machines using thulium oxide or other radio-active materials as the source of x-rays (Untermayer, '54, Army Medical Research Laboratory, '55), may substantially change the situation.

Individuals vary both in the absolute thickness of the subcutaneous "fat" at a given site and in its distribution over the body surface. For characterizing the pattern of *individual fat distribution* (*cf.* Garn, '55), as a component of body form, the number of sites should be large and skinfold measurements should be supplemented by soft-tissue x-rays of those areas (such as the trochanteric region or thigh) which are not suitable for skinfold measurements but which show marked individual differences. For purposes of classifying individuals along the *leanness-fatness* continuum—in field surveys, in schools, in clinics—the goal is to select a minimum number of sites which are suitable for skinfold measurements and provide, in proper combination, the optimal measure of relative adiposity (obesity).

The selection of sites involves several considerations, such as accessibility, precision in locating the site, relative homogeneity of the layer of skin and subcutaneous fat in a given region, and validity as an index of total fat (Brožek and Keys, '51). While measurements of skinfolds have been made for some 65 years (Richer, 1890), substantial progress in the systematic examination of the methodological matters has been made only in recent years (*cf.* Edwards, '50).

Considering all the criteria in terms of which the sites must be judged, the first prize goes unquestionably to the dorsal skinfold measured at the upper arm (over the triceps), with the skinfold parallel to the long axis of the arm. The upper-arm site has the great advantage of an almost universal accessibility in both men and women. However, the changes in the thickness of the subcutaneous fat from the elbow toward the shoulder are large and fairly rapid and if the measurement is to have meaning the location of the site must be rather precise.

The subscapular skinfold is readily measured and has the great advantage that the layer of skin plus subcutaneous tissue is fairly uniform in this region. Consequently, the demands for precision of localization are less severe than in the case of the arm.

A variety of other sites have been examined in terms of accessibility and validity. The site along the mid-axillary line, at the level of the xiphoid process appears especially advantageous (see Pascale, Grossman and Sloane, '55).

There are rapid changes in the thickness of the skinfold going horizontally from the umbilicus to the mid-axillary line as well as from the mammae toward the axillary fossa (with the arm pendant). This makes precise measurements in this region more difficult. Yet, in men, measurement of the skinfolds next to the umbilicus and to the nipple appear useful, even though at times it is impossible to lift a true "skinfold" in these areas so that fat individuals appear actually fatter. In some individuals with a "pot-belly" the maximum thickness of adipose tissue is located definitely below the level of the umbilicus and, for some purposes, the measurement of the *largest* abdominal "fold," to the right of the midline (sagittal plane), may provide useful information.

In order to make the readings comparable it is necessary to standardize not only the points on the body surface but also the pressure with which the calipers are applied. The need for constant-pressure calipers has been recognized some time ago and various experimental models were designed at the Laboratory of Physiological Hygiene, University of Minnesota, and elsewhere (Correnti, '47, Best, '54, Edwards *et al.*, '55).

It has been a general experience that a pressure of about 10 gm/mm^2 is, on several accounts, preferable to very low or to very high pressures (Brožek *et al.*, '54).

The skin should be lifted by firmly grasping the fold between the thumb and the forefinger of the left hand, about 1 cm from the site which is to be measured. It should be remembered that we wish to measure the thickness of a complete skinfold (double thickness of skin plus tela subcutanea) and should adjust accordingly the stretch of the skin enclosed between the thumb and the forefinger.

With sites and pressure standardized, normative data will accumulate rapidly. The raw data should be reported, preferably, in the form of actual distributions. Such data are given in table 8 for 238 adult men (members of the Minneapolis Fire Department). From the distributions norms can be calculated rapidly according to one's particular needs. With the skinfold distributions typically skewed to the right, centiles provide the simplest means for defining an individual's position along these continua.

The actual centiles, selected as normative reference points, will vary according to the investigator's or clinician's needs. When we draw an individual's "profile," including not only subcutaneous fat but also criteria of general size and of muscular and bony development, dividing the distribution into 10 units may be preferable (deciles). For grouping individuals into average, lean and fat, and very lean and very fat the 5th, 20th, 50th, 80th, and 95th centiles would be more useful than deciles. Such values, derived from distributions described in table 7, are given in table 8.

A tendency toward increased fat deposition with age and some changes in the distribution of subcutaneous fat are well known facts (Škerlj, Brožek and Hunt, '53). In the present sample there is a low but statistically significant correlation ($r = 0.276$) between age and the combined skinfold thickness. Consequently, norms derived from samples with narrower age ranges will provide a more precise framework for evaluating an adult individual's leanness-fatness. For other purposes the use of norms obtained for "healthy normal young men" can be justified. The purpose of this comment is to warn against blind use of *any* set of norms.

Among Minnesota firemen, for example, men with arm skinfolds of 9 mm or less thickness are definitely on the thin side; only one of five is so thin. But as shown in table 10, the norm for thinness would be differently placed in other population samples, even if care is taken to consider only clinically healthy men of given age.

Various procedures can be used for combining several skinfold measurements into a single index of leanness-fatness. Numerically, the

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TABLE 8

Distribution of skinfolds in a group of 238 middle-aged men

	UPPER ARM				SUBSCAPULAR				ARM PLUS SUBSCAPULAR		
INTERVAL	f	Σf	$\Sigma f\%$	INTERVAL	f	Σf	$\Sigma f\%$	INTERVAL	f	Σf	$\Sigma f\%$
4.0– 5.4	3	3	1.26	6.0– 8.4	12	12	5.04	11.0–15.9	11	11	4.62
5.5– 6.9	9	12	5.04	8.5–10.9	28	40	16.81	16.0–20.9	36	47	19.75
7.0– 8.4	27	39	16.39	11.0–13.4	41	81	34.03	21.0–25.9	45	92	38.66
8.5– 9.9	24	63	26.47	13.5–15.9	30	111	46.64	26.0–30.9	44	136	57.14
10.0–11.4	39	102	42.86	16.0–18.4	30	141	59.24	31.0–35.9	33	169	71.01
11.5–12.9	31	133	55.88	18.5–20.9	26	167	70.17	36.0–40.9	28	197	82.77
13.0–14.4	33	166	69.75	21.0–23.4	26	193	81.09	41.0–45.9	20	217	91.18
14.5–15.9	19	185	77.73	23.5–25.9	12	205	86.13	46.0–50.9	9	226	94.96
16.0–17.4	22	207	86.97	26.0–28.4	8	213	89.50	51.0–55.9	8	234	98.32
17.5–18.9	12	219	92.02	28.5–30.9	7	220	92.44	56.0–60.9	3	237	99.58
19.0–20.4	13	232	97.48	31.0–33.4	7	227	95.38	61.0–65.9	1	238	100.00
20.5–21.9	2	234	98.32	33.5–35.9	3	230	96.64				
22.0–23.4	4	238	100.00	36.0–38.4	4	234	98.32				
				38.5–40.9	3	237	99.58				
				41.0–43.4	0	237	99.58				
				43.5–45.9	0	237	99.58				
				46.0–48.4	1	238	100.00				

simplest approach is to add the skinfolds and obtain normative values based on the distribution of the added measurements. This was done for the upper arm and subscapular skinfolds in tables 8 and 9. When a larger number of sites has been used, the regression coefficients in a multiple regression equation provide a measure of the relative importance of specific sites in arriving at an overall estimate of leanness-fatness,

TABLE 9

Skinfold norms based on Minneapolis firemen (N = 238, mean age 41.6 years, range 25 to 63 years). Skinfolds were obtained with a pressure of 10 gm/mm square of the contact surface. The values were rounded to the nearest 0.5 mm

	CENTILE				
SKINFOLD	5TH	20TH	50TH	80TH	95TH
Upper arm	7.0	9.0	12.5	16.5	20.0
Subscapular	8.5	11.5	16.5	23.0	33.0
Arm plus subscapular	16.0	21.0	29.0	40.0	51.0

TABLE 10

Percentage of clinically healthy employed men who have arm skinfolds of 9 mm or less in thickness. The data on Cape Town (South Africa) and Sardinian samples were provided by Dr. A. Keys

NO. OF MEN	AGE Mean	 Range	GROUP	%
238	42	25–63	Minnesota Firemen	20
67	47	40–55	Cape Town Whites	19
93	47	40–55	Cape Town Coloured	56
113	47	40–55	Cape Town Bantu	60
97	43	30–60	Sardinian Police	51

using body density as a criterion of leanness-fatness. It is a distinct advantage of multiple regression analysis that it provides means for reducing the number of variables (skinfolds) to the most economic number. Where an external criterion (such as body density) is lacking, the technique of factor analysis (see Chen, '53) represents a useful tool of statistical analysis and economic description of fatness as an important component of man's physique and nutritional status.

COMMENT

In the sample of Minneapolis firemen, the combined measures of the bony and muscular development and of age accounted for about 60% of the interindividual variance in body weight ($R^2 = 0.5959$ for 7 independent variables, and $R^2 = 0.5918$ for 5 predictors of body weight). By comparison, the coefficient of determination for height, $r^2 = 0.2271$. For the corrected upper arm circumference, which is the best single predictor of weight, $r^2 = 0.3479$. Clearly, the gain from combining the measurements, together with age, is sizeable and $\hat{Y}$, the predicted weight, is a good deal more precise and biologically meaningful standard than can be obtained from the traditional height-weight tables.

However, the remaining limitations should be recognized. Firstly, there are the limitations inherent in the sample itself. Secondly, perhaps a better choice of the predictors of weight could be made. Certainly, the number of variables could be increased. Instead of calculating an approximate diameter of the arm, it might be preferable to actually measure the total external diameter of the arm and deduct one-half of the skinfold over the biceps and the triceps. In the present study only the dorsal skinfold (over the triceps) was measured.

While the weight "standards," derived in the way described in the body of the paper, represent a substantial improvement in the anthropometric description of nutritional status, there remains—as a part of the standard error of estimate—the components contributed by the unaccounted variation in the size of the skeletal musculature, in the density of the skeleton, and the size of viscera. The contribution of these components in a multiple regression equation is likely to be small. The fact is that at present it is unknown.

Last but not least, we deal here only with descriptive standards. The overwhelming bulk of the data on the significance of individual variations in physique, represented by the insurance data on mortality, is limited to variations of weight at different heights (Armstrong *et al.*, '51).

As in all descriptive standard, age is "built" into these reference values. However, it may be desirable (*cf.* Metropolitan Life Insurance Co., '42), to set the value of age at the level of "young adult," perhaps at 30 years. In table 6 this would simply reduce the value of the intercept ($-137.510 + 0.220 \times 30 = -130.910$), leaving 4 independent variables (height, the two lateral diameters, and the corrected arm diameter). However, should such an "absolute" standard be desired, the calculation of the prediction equation from a sample with a narrow age range, centering at the specified age (*e.g.* 30 years), might be preferable.

The thickness of skinfolds is a simpler and a more direct measure of leanness-fatness than standard (reference) weight. The measurement itself is fairly simple even though the procedure must be standardized—in terms of precise location, firm pressure exerted on the skinfold by the fingers in lifting the skinfold, constant distance between the spot at which the skinfold is lifted and at which the calipers are applied, constant pressure of the calipers—if the values are to be comparable from individual to individual and from group to group. A systematic use of skinfold measurements will unquestionably increase the contribution of anthropometry to the study of nutrition.

However, the matter of skinfolds and fatness is not as simple as it might appear at first sight. Some of the problems, such as the apparently differential rate of increase of the external (subcutaneous) and the internal fat, were noted elsewhere (Brožek, '55). The selection of the skinfold sites for field work involves a compromise between the several criteria of "desirability," such as accessibility and validity, as gauged from correlations with body density, an index of total body fat. Thus the chest skinfold, measured in the juxta-nipple position, has shown repeatedly a high validity for normal young men (Brožek and Keys, '51; Pascale, Grossman and Sloane, '55). Yet, the steep gradient of the subcutaneous layer in this region may make the use of the site of dubious value in other hands. In any case, it can not be used in studies including older girls and women.

A point requiring additional thought concerns the use of absolute vs. relative skinfolds, calculated as an index in which the skinfold thickness is related to total body length or to the length of a body segment (*e.g.* upper arm skinfold and the length of the upper arm). The fact is that absolute skinfolds, in reasonably homogeneous age groups, show no relationship to body length. Thus in a sample of 179 Minneapolis firemen, 30 to 49 years old, the correlations between height and the arm skinfold, the subscapular skinfold, and the combined (total) skinfold thickness yielded r's of 0.022, 0.005, and 0.012, *i.e.* the two aspects of the body are independent. On the average, in the given sample the short men and the tall men have skinfolds of about the same thickness, and a single set of norms would appear satisfactory. On the other hand, in relative terms (Skinfold/Height) the taller men would be thinner.

SUMMARY AND CONCLUSIONS

"Nutritional status" (nutriture) has several facets, described in terms of clinical examination, laboratory (biochemical) analyses, and measurements of body size and body composition. It has been recognized and reemphasized more recently by the Joint FAO/WHO Expert Committee on Nutrition ('51, '55) that anthropometry provides important, though limited, tools for the assessment of nutritional status. It was noted that the physical dimensions of the body depend, in part, on the individual's nutritional history. The need for objective specification of body or skeletal "types" in the assessment of body weight was pointed out. Among the anthropometric measurements useful for throwing light on the nutritional state the importance of skinfold thickness was underlined. The thickness of the subcutaneous fat layer, whether measured by the skinfold caliper or on suitable roentgenograms, was considered to provide a more satisfactory index of relative fatness and nutritional status than the body weight. Finally, the means of estimating muscular development of an individual from combined measurements of the circumference of the extremities and the subcutaneous fat thickness were noted.

In the present study these problems were considered on the basis of empirical data obtained on 238 members of the Minneapolis Fire Department.

Height (1), cristal height (2), bicristal (3) and biacromial (4, diameter, the distance between the epicondyles of the humerus (5), the diameter of the upper arm less the skin and subcutaneous adipose tissue (6), and age (7) were used as predictors of body weight. The multiple $R = 0.770$. Eliminating two variables (2, 5) which did not contribute significantly, $R = 0.769$.

The deviations from such a weight standard, expressed in kg or as a ratio of the actual to standard weight, can serve as a substantially improved measure of adiposity. By constrast, the individual's deviations from the standard, obtained by using the traditional height-weight tables, are complex values in which the contributions of the variations in body build, especially in the lateral size of the skeletal framework, muscular development, and adiposity are not separated.

The problem of adiposity can be approached more directly by measuring skinfolds. The questions of standardization were examined and preliminary descriptive norms for adult men were provided.

Some of the unsolved problems, both at the level of anthropometric description and biological interpretation of individual differences in nutritional status, were noted.

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BODY BUILD AND BODY WEIGHT IN 25-YEAR-OLD ARMY MEN

BY ROBERT M. WHITE

Quartermaster Research and Development Center
Natick, Massachusetts

THE variability of body weight and its general relationship with stature is a familiar phenomenon in human biology. However, the problem of the effect of the size of the frame upon variability in body weight among men of the same stature is one which certainly merits further examination. The following material represents an attempt to investigate this question by considering the factor of laterality in body build.

The basic material utilized in this analysis was taken from anthropometric data collected by the U. S. Army Quartermaster Corps in 1946. At that time, body measurements were obtained on approximately 85,000 soldiers who were being separated from the Army during the demobilization process.

In order to eliminate the variability of weight with age, the sample was limited to men in the 25-year-old group. A series of approximately 3550 American-born White males was available for this analysis. The data actually utilized, however, were based on a series of approximately 2650 men. Body weights in this series are nude weights; stature was taken without shoes, and the body measurements were taken without clothing.

In this group, the total range of stature is from 59 to 77 inches; owing to small numbers of men at the extremes, a stature range of from 62 to 75 inches was selected for analysis. Body weight in this group varies between 100 and 270 pounds. The frequency distribution of stature in the series is normal, while the frequency distribution of weight shows the characteristic skewness to the right. Mean stature for this group is 68.6 inches, with a standard deviation of 2.4 inches, while mean weight is 157.0 pounds with a standard deviation of 20.7 pounds. The coefficient of correlation between stature and weight is +.451.

The available anthropometric data include several body diameters, as well as circumferences. Since it was felt that a diameter would offer a better measurement of laterality than a circumference, bi-deltoid, chest breadth, chest depth, and bi-iliac diameters were selected for consideration. Of these, the chest breadth and bi-iliac diameters seemed to offer the most promise since they are diameters taken between points on the bony framework of the body and are affected less by intervening fat. These two diameters were taken with an anthropometer, with pressure being applied.

A bi-variate distribution of stature and chest breadth diameter was then prepared. Mean chest breadth for this series is 11.2 inches, with a standard deviation of .8 inches, while the coefficient of correlation with stature is +.271. A regression line, derived from the regression equation of chest breadth on stature was plotted on the bi-variate chart. With this regression line as a base, the frequency distribution of chest breadth was divided into three groups by utilizing the probable error of the regression. These three groups may be taken to represent men with small, medium, and large chest breadths in a 25, 50, and 25% ratio.

The mean body weight was then calculated for the small, medium, and large chest breadth groups for each inch of stature. There was considerable variation in these means of body weight; the medians showed even more variability. In an attempt to reduce some of this variability, separate bi-variate distributions of stature and weight were prepared for the small, medium, and large chest breadth groupings. Values for weight calculated from the regression equation of weight on stature for the three groupings of chest breadth are belived to be more consistent and reliable than the simple means.

A similar analysis was carried out with the data for stature and bi-iliac diameter. The mean bi-iliac diameter for this series is 11.4 inches, with a standard deviation of .8 inches, and the coefficient of correlation with stature is +.336, slightly higher than that of chest breadth. As in the case of chest breadth, values of weight for groups of small, medium and large bi-iliac diameters for each inch of stature were obtained.

The results from these two analyses are shown in table 1. This table gives 6 mean weights for each inch of stature between 60 and 78 inches;

one for each group representing small, medium, and large chest breadths, and similarly one for each group representing small, medium, and large bi-iliac diameters. Since the analyses were based upon stature data between 62 and 75 inches, the weight values for 60, 61, 76, 77 and 78 inches of stature have been extrapolated. The limits of the chest breadth groupings for 60 inches of stature are: small, below 10.0 inches; medium, 10.0 to 11.0 inches; and large, above 11.0 inches of chest breadth. At 78 inches of stature, the limits are: small, below 11.5 inches; medium, 11.5 to 12.5 inches; and large, above 12.5 inches. Similarly the limits of the bi-iliac groupings for 60 inches of stature are: small, below 9.9 inches; medium, 9.9 to 11.0 inches; and large, above 11.0 inches, while at 78 inches of stature, the limits are: small, below 11.9 inches; medium, 11.9 to 13.0 inches; and large, above 13.0 inches.

TABLE 1

Mean weights of 25-year-old army men (pounds)

STATURE (inches)	CHEST BREADTH Small	Medium	Large	BI-ILIAC DIAMETER Small	Medium	Large
60	115	127	141	121	125	136
61	118	130	145	124	129	140
62	122	134	148	127	132	144
63	125	137	152	130	136	147
64	128	141	156	133	139	151
65	132	144	160	136	143	155
66	135	148	163	140	147	159
67	138	151	167	143	150	162
68	142	154	171	146	154	166
69	145	158	174	149	157	170
70	148	161	178	152	161	173
71	152	165	182	155	164	177
72	155	168	185	158	168	181
73	158	172	189	162	171	184
74	162	175	193	165	175	188
75	165	179	197	168	179	192
76	168	182	200	171	182	196
77	172	186	204	174	186	199
78	175	189	208	177	189	203

For many years, tables of "ideal" or "desirable" weights have been published by insurance companies, based upon medico-actuarial studies of large series of insured individuals. A table of this type, published by the Metropolitan Life Insurance Company of New York, is entitled, *Desirable Weights for Men age 25 or Over.* This table represents minimum and maximum weights for men with small, medium, or large frames, for each inch of height between 62 and 75 inches. The range of weight for each inch of stature and each type of frame is approximately 10 or 12 pounds. In this table, weights are given "as ordinarily dressed," and heights are given "with shoes." The small, medium, and large frame categories are not defined.

The Army data indicate slightly higher weights for men with small bi-iliac diameters than for men with small chest breadths; in the medium body build group, weights are virtually the same for chest breadth and bi-iliac diameter; while in the third group, weights are higher for men with large chest breadths than for men with large bi-iliac diameters. The maximum figures for weight in the small, medium and large frame categories of the Metropolitan table come close, in general, to the mean weights based upon the bi-iliac diameter of the 25-year-old Army men. In any case, the area bounded by the lower and upper limits of weight in the Metropolitan table fell within limits indicated by lines representing one probable error above and below the line of mean weights, based upon either chest breadth or bi-iliac diameter.

In addition to the investigation of the effect of laterality on body weight, involving chest breadth and bi-iliac diameter, another phase of the present study consisted of a similar analysis based upon trunk height. The trunk measurement is essentially sitting height less the head and neck, and represents the length of the trunk or torso of the body. In the present series, mean trunk height is 23.1 inches, with a standard deviation of 1.1 inches, and the coefficient of correlation with stature is +.602. The same procedure as described above was followed for the analysis of trunk height, with the following results. Owing to the comparatively high positive correlation between trunk height and stature, the three groupings of trunk height, through use of the probable error of the regression, were not nearly as well-defined as in the case of the diameters. The mean weights which were then calculated for the small, medium, and large trunk height groups were also quite irregular. It may be concluded, therefore, that a preliminary investigation of the relationship between trunk height and stature indicated that a length measurement, such as trunk height, is not as satisfactory for the consideration of variability in body weight as is a diameter.

In summary, an analysis of weight and body build was carried out on a series of approximately 3550 25-year-old White Army separatees. For each inch of stature, mean weights are presented for small, medium, and large groupings of chest breadth and bi-iliac diameter.

The material presented in this paper represents only a preliminary investigation of the problem of laterality in body build. However, the weights presented in table 1 are those for definite categories of body size as determined by the use of chest breadth and bi-iliac diameters.

The weights shown in the Metropolitan Life Insurance table, although they approximate fairly closely the Army values, are for categories of body size in which the determination of the size of the frame is not specified or defined in terms of any body diameter.

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VARIABLE FACTORS IN SKELETON WEIGHT

BY MILDRED TROTTER
Department of Anatomy, Washington University,
Saint Louis, Missouri

"THE skeleton is a living and not an inert tissue. New bone is constantly being formed and bone is ever being resorbed, not necessarily at the same rates in all bones or even in any one area of a given bone" (Howard, '51). However, it is believed that the skeleton changes less in weight than do other components of the body when there is either a marked increase or decrease in total body wight.

In the field of nutrition it is desired to know the contribution made by the skeleton to total body weight. It was assumed in 1950 by the authors (Keys *et al.*) of *The Biology of Human Starvation* "that on the average 16% of the body mass is normally provided by the bones." Of the three individual determinations cited, the lowest was 14.8% found by Mitchell *et al.* in 1945. In 1953 another body was analyzed in Mitchell's laboratory and its skeleton weight in per cent of total body weight was 17.6%, matching exactly the average arrived at by Wilmer in 1940 from a search of the literature. These scant data support the premise that the weight of the skeleton is relatively stable in its relationship to the body as a whole.

Matiegka had proposed in 1921 that the weight of the skeleton in the living could be estimated from a formula based on certain measurements. These are stature (S) and the maximum transverse diameter of the lower end of arm, forearm, thigh and leg ($4TD$). The indicated sites for measurement are bony prominences which are relatively free from overlying soft parts. The formula is:

$$\text{Stature, cm} \times (\text{average } 4TD, \text{cm})^2 \times k_1 = \text{Skeleton weight, gm.}$$

The coefficient, k_1, which is still to be determined but was believed to be from 1.0 to 1.2, was recommended to "equalize all arisen errors."

Recently Matiegka's formula was tested on a series of 24 White male skeletons in the Terry Collection with an age range from 18 to 87 years (Trotter, '54). The skeletons were selected for completeness and age with 3 or 4 in each decade. The statures of the cadavers from which the skeletons came were known, but the transverse diameters were taken on the bones directly rather than before skeletonization. It was found that the independent variables, stature and the transverse diameters, involved in Matiegka's formula have a statistically significant multiple correlation coefficient with the dependent variable, total skeleton weight; it is .7362 with a probability of $<.001$ and a standard error of estimate of 567 gm. It should be noted that this probability was erroneously reported as $<.01$ in the previous publication.

In an attempt to find other variables which are now highly correlated with skeleton weight or which may have a bearing on this problem it was discovered that:

age is not significantly correlated with skeleton weight;

stature has a correlation coefficient with skeleton weight of .6909 with a probability of $<.001$; and

femur weight has a correlation coefficient with skeleton weight of .9591 with a probability of $<.001$.

Since the weight of the femur, or rather the average weight of the pair of femurs, has such a high correlation coefficient with the total skeleton weight, certain other factors concerning the femur, which could be determined in the living subject, were tested. These include average maximum length of a pair of femurs, average bi-epicondylar diameter, sum of the outline areas of photographs of actual size taken from an anterior view and, finally, sum of areas of compact bone in the middle half of the femurs shown by X-ray, taken with the tube six feet from the film, postero-anterior view. The areas were measured with a planimeter. The tests show that:

femur length has a correlation coefficient with skeleton weight of .5833 with a probability of $<.01$;

bi-epicondylar diameter has a correlation coefficient with skeleton weight of .5344 with a probability of $<.01$;

area of femurs has a correlation coefficient with skeleton weight of .7159 with a probability of $<.001$; and

area of compact bone has a correlation coefficient with skeleton weight of .7634 with a probability of $<.001$.

The femur is the longest bone in the body and the heaviest single bone. The skull is heavier and may be considered as a unit since only the mandible is a separate bone. The hip bone, largely cancellous, is also relatively heavy, although not as heavy as either femur or skull. Because of Matiegka's suggestion that diameters of limb bones are indicative of the weight of the skeleton, the greatest breadth of the pelvis and the greatest antero-posterior and transverse diameters of the skull were tested, also. The indication of correlation between either of these diameters or of the weight of the hip bone with weight of the total skeleton was not sufficient to warrant further study.

These findings show that the configuration of the internal structure of bone is a more significant factor than either size or age in determining its weight. In long limb bones is found a greater proportion of compact (*substantia compacta*) to cancellous or spongy (*substantia spongiosa*) bone than in other bones excluding the skull. When the balance between resorption and formation of bone in an adult is lost and resorption becomes greater than formation it is the cancellous bone which is reduced first. Experimental studies on rat femurs, for example, have shown that the cancellous bone was reduced after a period of low calcium intake; when the period was extended and the intake was less, the reduction included the internal portion of the compact bone (Ellinger, Duckworth, Dalgarno, '52). The comprehensive work by Amprino and Bairati ('36) includes a survey of the compact bone of the femoral diaphysis of 94 individuals from 8 months prenatal to 94 years of age. They found that this imbalance between resorption and formation occurs in man after middle life. The process of resorption of the internal wall of the diaphysis is no longer compensated for by redeposition, so that a spongy stratum of bone occupies the area which has been the most internal portion of the compact substance.

Does this process of change and reduction of the internal architecture of the femur occur in all bones of the skeleton? And, what change, if any, occurs in the chemical composition of bone? For the most part, analyses of bones, both animal and human, have been made on small samples of a particular bone, and most often of a selected long limb bone. The evidence found has been extrapolated to include not only the entire bone, but, also, the entire skeleton. In 1953, after analyzing the second cadaver, Mitchell and his co-workers at the University of Illinois concluded that a single bone is not likely to give a true estimate of the composition of the entire skeleton. For each cadaver, they had analyzed three bones separately, the remaining bones of each skeleton were mixed and samples only were studied.

A dry, fat-free bone is composed of organic and inorganic matter. Whole human bones may be rendered dry and fat-free, weighed, ashed, and weighed again. The difference between the weight of the ash and the weight of the dry, fat-free bone before ashing is the weight of the organic component. In our laboratory the individual bones (with few exceptions) of 7 male skeletons from one Negro and 6 White cadavers ranging in age from 45 to 89 years have been so treated (Trotter and Peterson, '55). In addition, the long limb bones of 10 more White male cadavers were ashed. The weight of the ash of each bone was reduced to a percentage of its dry, fat-free weight.

The average percentage ash weights of the long limb bones of 16, or, of all but one, of these cadavers show only small differences (table 1). The long limb bones of this one cadaver are not included in these averages because the percentage ash weights are so much lower than in the others. This reduction in percentage ash weight was found in most of the bones of this skeleton as will be shown later.

TABLE 1

Average of ash weights in per cent of dry, fat-free weights of long limb bones from 16 cadavers

BONE	AVERAGE	RANGE
Femur	66.5	65.0–68.1
Tibia	66.5	63.4–68.5
Fibula	66.9	62.8–69.2
Humerus	66.6	63.2–68.9
Radius	67.0	63.2–69.5
Ulna	67.2	64.4–69.6

When the averages of the percentage ash weights of these bones from the 8 cadavers 60 years and less are compared with those of the 8 cadavers over 60 years of age it is found that each bone of the younger group shows a slightly higher percentage than its counterpart in the older group. However, the average percentage ash weight of the bones of the younger group is only 0.5% higher than of the older group and a much larger series is needed in order to test its significance. A more pertinent test would be a comparison of this older group with cadavers in the third decade of life.

The percentage ash weights of the 7 complete skeletons (table 2) are quite uniform with the exception of the 65 year old. This skeleton has a percentage ash weight of 54.5%, from 10 to 12% lower than any one of the other 6, which range from 64.8% to 66.9.%

The percentage ash weights of most of the individual bones comprising each skeleton vary less than 5% from the percentage ash weight of the complete skeleton. In the 60 and 72 year old skeletons, there are no bones which vary as much as 5%. In the 89 year old, only the left patella has a percentage ash weight which is more than 5% below that of the total skeleton. In the 45 and 56 year old skeletons there are three bones in each with low percentage ash weights; for the former: sacrum, right clavicle and right hip bone, and for the latter: sternum, sacrum and left hip bone. (The bone with the lowest percentage ash weight is given first and the others in order of increasing value.) In the 73 year old skeleton the percentage ash weight of the sternum and sacrum are each approximately 10% below that of the complete skeleton; the vertebrae (excluding the cervical) are equally low and the left and right ribs, 6% and 8%, respectively. The bones of the 65 year old skeleton which have percentage ash weights as much as 5%, or more, below that of the total skeleton are sacrum, sternum, and both hip bones, in that order, then vertebrae, right clavicle, ribs, ulnae, radii, and right fibula. Thus, it appears that when a reduction in percentage ash weight of a skeleton takes place, it occurs first in bones which are largely cancellous. As the amount of reduction increases, it is extended also to include long limb bones which have a greater proportion of compact substance. The percentage ash weights of the cranium and mandible

TABLE 2

Ash weight in per cent of dry, fat-free weight of complete skeletons and range among individual bones of each

AGE (YEARS)	COMPLETE SKELETON	RANGE AMONG BONES
45	65.2	57.6–69.7
56	65.3	55.2–69.0
60	66.9	63.7–68.4
65	54.5	28.7–71.3
72	65.6	63.3–68.5
73	64.8	53.4–69.9
89	64.9	49.2–69.8

are consistently high. In 5 skeletons, the mandible has the highest percentage ash weight; in one it is exceeded by the vertebrae and in another by the left radius. The presence of teeth does not seem to increase the percentage ash weight. The differences between the highest and lowest percentage ash weights among the bones of each skeleton range from 4.7 in the 60 year old to 42.6 in the 65 year old.

It is of interest to compare the percentage ash weights found in the two skeletons at the University of Illinois with those at Washington University (table 3).

TABLE 3

Ash weight in per cent of dry, fat-free weight of bones at the University of Illinois and at Washington University

AGE (years)	BONE Tibia	 Ulna	 Rib	Total skeleton
		University of Illinois		
35	66.3	64.0	57.5	56.7
46	69.3	65.6	62.1	56.9
		Washington University		
65	55.9	48.0	44.8	54.5
(6 others) 45–89	66.7	67.3	63.1	65.5

The 65 year old skeleton at Washington University has a total percentage ash weight which differs from the skeletons at Illinois by less than 3%, but the tibia, ulna and rib percentages are considerably lower. Conversely, the other 6 skeletons at Washington University have total percentage ash weights which are considerably higher than the skeletons at Illinois, but the tibia and ulna percentages are approximately the same. In each of the 7 skeletons studied at Washington University the total percentage ash weight matched rather closely that of the long limb bones, but for both skeletons at Illinois the total percentage ash weights were considerably lower than those of the long limb bones. It is suggested that this discrepancy between results from the two laboratories may be explained by the fact that at Illinois except for two long limb bones and one rib of each skeleton which were studied in their entirety, a sampling technique was utilized for the remaining bones of the skeletons.

From the evidence provided by these studies it is indicated that the process of metabolism in the adult does not invariably maintain equilibrium between the organic and inorganic components of the skeleton, and further, that such imbalance is not uniform among the individual bones, but rather a progressive change which is initiated in one region and extended to other regions in an orderly sequence.

It is suggested that the term "demineralization" be limited in its usage to signify a reduction in the proportion of the inorganic component to the organic component of a bone, and not to signify a degree of atrophy in which there is a comparable reduction of both components in proportion to the size of the bone. As an example, imbalance between the components is present in osteomalacia through failure of calcification of newly deposited osteoid matrix, whereas balance between the components is maintained in osteoporosis even though there may be a marked degree of atrophy.

Since the size of a bone is one of the variable factors contributing to its weight a more critical determination of this factor than straight-line measurements is indicated. A measure of the volume enclosed within the surface of the bone might be useful in evaluating its weight. Determination of the relationship between volume and weight of each bone of an adequate series of complete skeletons with a wide age range would provide evidence of either uniformity and/or variance in weight per unit volume of the same bone of different skeletons. On the same series of skeletons the actual amounts of the organic and inorganic components should be found, in addition to the proportion of these components to each other. It would be interesting, also, to explore the degree of correlation between the weight/volume ratio of the bones and their "densities," determined from X-rays.

In summary, there has been presented:

an analysis of the degree of correlation between age, stature and certain diameters of the skeleton and weight of the skeleton;

evidence that the internal structure of the femur is more highly correlated with weight of the skeleton than diameters;

data which show that the ratio between the organic and inorganic components of the skeleton is usually constant among the individual bones, but that in some skeletons the inorganic components may be reduced, first in bones which are largely cancellous and later in long limb bones which have a greater proportion of compact substance.

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SKINFOLD MEASUREMENTS IN YOUNG AMERICAN MALES

BY RUSSELL W. NEWMAN
Quartermaster Research and Development Command,
Natick, Massachusetts

INTRODUCTION

THE growing use of skinfold measurements obtained with constant-pressure calipers has emphasized the need for large-scale surveys of selected populations to develop standards against which future studies can be compared. No single survey will be adequate in this field, even within one population, because age (Brožek, '52), sex (Škerlj, Brožek, and Hunt, '53), and physical activity differences (Brožek, '54) will require subsampling beyond the capacity of most surveys. This report is not definitive, even in its selected sample of young American adult males, but it should provide data more extensive than presently available.

The sample reported here consists of approximately 2,400 young men measured shortly after induction into the U. S. Army and before the start of basic training. Two thousand of these were re-measured after 6 or 7 weeks of training and an analysis of the changes which occurred in these men will be reported later. The series used here consists of 2,017 American-born White males and 361 American Negro males. Certain comparisons between these racial groups have been published (Newman, '55). It was concluded that no great error was introduced by using the same regression equation for converting skinfold measurements to body fat, although the original equation was based solely on White college students.

This report will cover two aspects of the skinfold measurements obtained on these men. One, the basic statistics on the measurements will be presented for the use of other workers in the field. Two, geographical and racial groups will be contrasted to show interesting differences between regional subsamples.

The measurements were collected at 7 Army basic-training centers in the eastern and southern portions of the country, from Maryland to Arkansas. Because it was necessary to resurvey the men before the end of basic training, no western centers could be visited in the time available. The men were not individually selected for this survey, entire training units of company size being processed at each installation. The sample consists of volunteers and of men inducted into the Army through Selective Service from the eastern half of the country during the spring of 1953. It is a series which has been medically screened for military service, with very short and tall men as well as the very light and heavy individuals eliminated. The age distribution of the series is relevant because of the well-known relationship of increasing fat with age. The mean age of the Whites was 20.7 years while that of the Negroes was 20.8. The variability of age was restricted (17 to 28 years old), as might be expected in a sample of military inductees.

The geographical restrictions of the sample will be apparent when regional area comparisons are presented later in this paper. Only 21 individuals are represented from the area west of the Great Plains. It is possible that the inclusion of a proportional sample from this area might alter the statistics on skinfold measurements and derived body fat, but it is doubtful that a radical revision would be required.

STATISTICAL VALUES FOR THE RACIAL SERIES

Ten measures have been used in the analyses. Seven of these (stature, weight, and 5 skinfolds) were taken on the men and three (relative weight, fat-free weight, and body fat) were calculated from the data. Stature was recorded as the maximum height to which the subject could stretch with the feet firmly on the ground and the head and eyes level. Weight was obtained on the nude subjects with a physician's type scale. The skinfold measurements have been described in a previous paper (Newman, '55). Relative weight, *i. e.*, actual body weight expressed as percentage of the so-called "standard" weight for height and age, was calculated from the data provided by the medico-actuarial mortality investigation of 1912 as given in Davenport ('23). The limitations of this standard in terms of body composition have been shown by Brožek and Keys ('50) and its doubtful applicability to a military population pointed out (Newman, '52). It has been included here because it remains a common standard even if an outmoded one. Body fat was calculated by the formula of Brožek and Keys ('51). Fat-free weight is body

TABLE 1

Presentation of White and Negro measures

2,017 Whites

	Mean	S. D.	PERCENTILE				
			5th	25th	50th	75th	95th
Stature (in)	68.9	2.5	65.0	67.2	68.9	70.6	73.2
Weight (lb)	154.0	22.7	122.6	138.1	151.4	166.3	195.5
Relative weight (percent)	105.2	13.7	87.6	96.5	103.5	112.6	131.4
Fat free weight (lb)	142.1	15.6	118.0	131.0	141.5	152.6	168.3
Body fat (percent of wt)	7.4	5.1	2.2	3.8	5.8	9.3	17.9
Chest skinfold (mm)	10.0	6.6	4.4	6.4	8.6	11.9	23.6
Arm skinfold (mm)	11.4	5.4	5.2	8.0	10.7	14.6	22.2
Back skinfold (mm)	13.6	6.0	8.2	10.3	12.1	16.1	25.9
Knee skinfold (mm)	15.0	5.8	8.5	11.2	14.4	18.5	26.4
Abdomen skinfold (mm)	14.6	7.9	6.9	9.5	12.6	18.5	31.8

361 Negroes

	Mean	S. D.	PERCENTILE				
			5th	25th	50th	75th	95th
Stature (in)	68.3	2.6	64.2	66.7	68.2	69.8	72.8
Weight (lb)	151.0	18.5	122.9	139.3	148.8	161.8	183.3
Relative weight (percent)	105.4	10.9	91.1	98.3	104.5	111.9	124.3
Fat free weight (lb)	144.5	14.9	121.1	133.9	143.4	154.4	169.4
Body fat (percent of wt)	4.6	3.4	1.1	2.7	3.7	5.5	10.0
Chest skinfold (mm)	6.5	3.7	4.1	4.9	5.9	7.8	12.0
Arm skinfold (mm)	8.2	4.0	4.4	6.1	7.8	10.0	15.8
Back skinfold (mm)	12.2	4.3	8.3	10.2	11.6	14.0	21.2
Knee skinfold (mm)	12.9	4.5	7.9	10.2	12.5	16.0	21.4
Abdomen skinfold (mm)	11.7	5.7	6.5	8.7	10.6	13.6	25.0

weight minus the calculated weight of the fat; it has been equated with the lean body mass (Behnke, '41).

The usual statistics on the racial samples are presented in table 1. Percentiles have been included along with the mean and standard deviation because those variables which include body fat are definitely skewed. A visual comparison of the means and medians (50th percentile) shows that only stature is truly symmetrical in distribution, with fat-free weight approaching symmetry.

RACIAL COMPARISON

It is apparent that the racial groups differ considerably in the amount of body fat. This has been graphically illustrated in figure 1 by plotting smoothed-curve distributions for body fat in terms of percentage frequency to equalize the numerical representation of the groups. The Negroes are not only more lean than the Whites, but their frequency distribution is remarkably narrow.

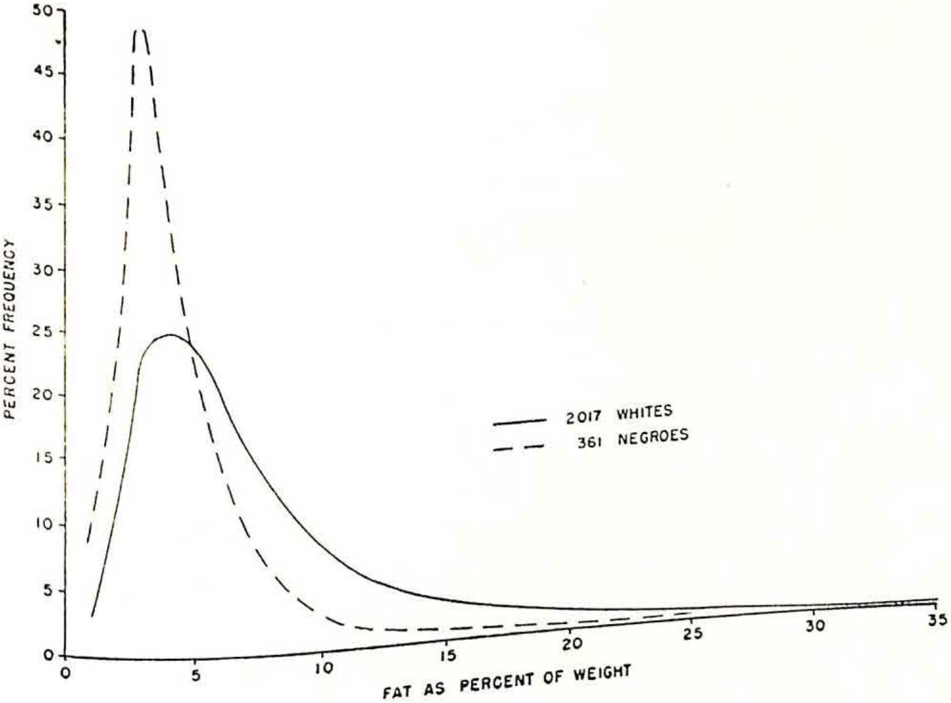

FIG. 1. DISTRIBUTION OF BODY FAT.

The statistical significance of the differences between the White and Negro mean values has been investigated by the use of Student's *t*-test. Unfortunately, this test presumes a "normal" distribution in both groups, a condition which is not fulfilled in most of these measures. Also, the large numbers of individuals involved result in statistical significance for minute differences which can have no biological meaning. All measures listed in table 1 show statistically significant differences at the 1% level except relative weight. Three of the measurements, body fat, chest skinfold, and arm skinfold, showed "*t*" values of much higher magnitude, indicating maximum differences in these variables. Since body fat is calculated from the measured thickness of chest and arm skinfolds (plus abdominal skinfold), it is these sites of subcutaneous fat which appear most distinctive between the racial groups. This phenomenon was noted in another type of analyses on this series and a possible explanation presented (Newman, '55).

REGIONAL COMPARISONS

In the following regional subsamples of these racial groups the analyses have been conditioned by the geographical distribution available in the series. It was necessary to select regional groupings which provided reasonable environmental and historical continuity without unduly reducing the sample size. Although no geographic selection which uses political boundaries can completely satisfy biological analyses, a regional grouping of states where the men were born was essential, and the Selective Service areas utilized in previous Quartermaster Corps anthropometric surveys were selected. These areas are shown in figure 2. Two regions, the Mountain States and the Pacific Coast, have not been included for lack of adequate representation.

NORTHERN AND SOUTHERN WHITES

A two-fold grouping of the White subjects into Northern and Southern is a convenient breakdown of the 7 regions shown in figure 2. Four northern regions (New England, Middle Atlantic. East and West North Central) and three southern regions (South Atlantic, East and West South Central) delineate the traditional boundaries. The means and standard deviations of the regional groupings are shown in table 2.

Within the same limitations mentioned in the Negro-White comparisons and with some doubt as to their applicability, a *t*-test of mean

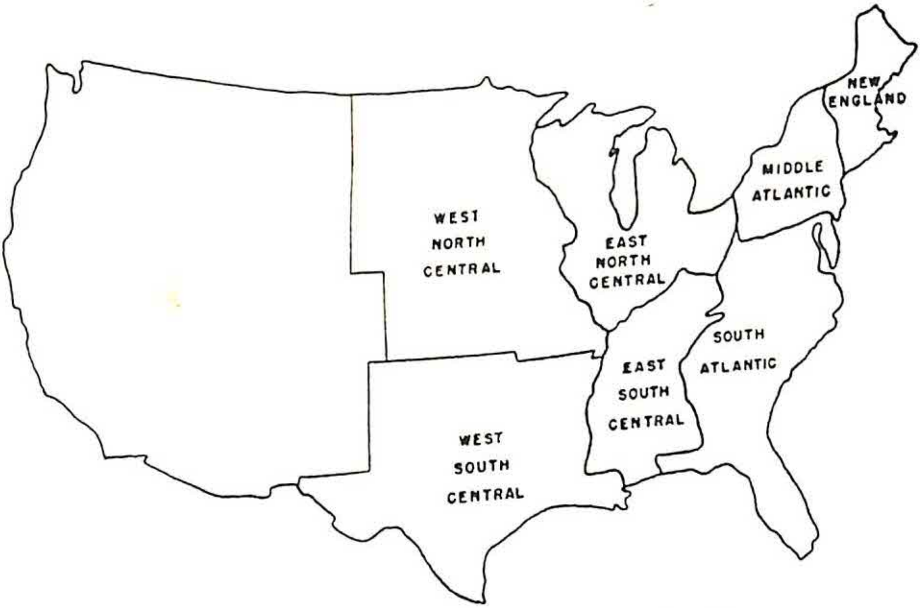

FIG. 2. REGIONAL GROUPING OF NATAL STATES.

TABLE 2

Comparison of Northern and Southern Whites

	1,283 NORTHERN WHITES		713 SOUTHERN WHITES	
	Mean	S. D.	Mean	S. D.
Stature (in)	69.0	2.5	69.0	2.5
Weight (lb)	156.3	23.5	150.3	20.8
Relative weight (percent)	107.4	14.0	103.0	12.9
Fat free weight (lb)	143.4	15.8	139.9	15.0
Body fat (percent of wt)	7.9	5.3	6.4	4.6
Chest skinfold (mm)	10.6	6.9	9.0	5.7
Arm skinfold (mm)	12.0	5.6	10.4	5.0
Back skinfold (mm)	14.2	6.4	12.4	5.2
Knee skinfold (mm)	15.7	6.0	13.9	5.4
Abdomen skinfold (mm)	15.3	8.2	13.4	7.1

difference indicated statistically significant differences such as were found between Whites and Negroes. Except for height, the southerners have uniformly lower values, including both fat-free weight and those measures influenced by body fat. This indicates that the sizable weight difference (6 pounds) is not solely a matter of leanness-fatness; the southerns are lightly built with a demonstrably paucity of muscular tissue.

NORTHERN AND SOUTHERN NEGROES

An investigation of the Negroes on the basis of birthplace is complicated by two problems; one, over 80% of the Negroes were born in the south; and, two, there was an expectably large number of Negroes who were born in the south but who entered the Army at northern induction centers. For these reasons, the Negroes were separated into 4 groups on the basis of birthplace and induction center. Since it is apparent that body fat is the crucial element of geographical differences, only this variable has been used; the data are presented in table 3.

TABLE 3

Comparison of Northern and Southern Negroes in terms of body fat (as percentage of weight), estimated from skinfolds

	PERCENTAGE OF 361 Negroes	Number	BODY FAT Mean	S. D.
Born in the south; inducted in the south	66	239	4.2	2.6
Born in the south; inducted in the north	15	53	4.9	3.7
Born in the north; inducted in the north	18	64	5.4	4.0
Either birthplace; inducted in the north	33	117	5.2	3.9

It will be noticed that one possibility was omitted in this table: Negroes who were born in the north and were inducted in the south. Only 5 individuals fell into this category and this was much too small a sample for comparative purposes. It was not determined at what age the individuals born in the south but inducted in the north migrated or whether their residence was continuous. The *t*-test showed no statistically significant mean difference in body fat between the southern Negroes on the basis of place of induction, but those born and inducted in the north differed from those born and inducted in the south at the 5% level of significance. Negroes inducted in the north, regardless of birthplace, differed significantly at the 5% level from those inducted in the south. This set of comparisons suggests either that a selective migration has occurred or that the northern environment (climatic, cultural, economic) leads to greater fat deposition. The findings on Negroes who were born in the south and inducted in the north, although not significantly different in body fat from those who remained in the south, strengthen the latter hypothesis.

REGIONAL COMPARISON IN WHITES

The large number of White soldiers available from the geographic regions shown in figure 2 can be listed by area and still maintain adequate samples. Only two regions, New England and West South Central, are sparsely represented. The means and standard deviations for the regional groups are given in table 4.

This table gives some idea of the proportional representation which went into the north-south comparison in table 2. There is a suspicion which would be difficult to verify because of the unequal numerical representation of the states that a band of relatively great obesity with medium muscularity stretches from New Jersey to Chicago and that this contrasts with a parallel band of leanness and low muscularity in what might be called the Deep South. New England and the Plains States appear peripheral to these concentrations of fatness and leanness but high in fat-free weight (muscularity). Hooton ('48) reached this conclusion in an analysis of body-build photographs of approximately 40,000 U. S. Army men. He found that the Middle Atlantic region had the highest concentration of fat men, and the highest percentage of what he termed muscular types occurred in New England. He ascribed the origin of the two diverse belts of body composition to the importance of national extraction. He says:

> Clearly the principal reasons why the Middle Atlantic and New England districts show such profusions of the well-muscled types and why the former district is so high in heavy men have to do with the population of recent foreign origin in these industrialized areas, which includes so many Southern, Eastern, and Central Europeans. These countries provide excesses of short, stocky, muscular men—even down to the second generation born in this country. On the other hand, districts such as Southern Atlantic and East South Central are mostly Old American (which implies mainly British and Irish derivation) and, consequently, the slender, tallish types of lighter musculature are likely to come in disproportionately large numbers from such regions.

TABLE 4

Regional values for White soldiers

	NEW ENGLAND		MIDDLE ATLANTIC		EAST NORTH CENTRAL		WEST NORTH CENTRAL		SOUTH ATLANTIC		EAST SOUTH CENTRAL		WEST SOUTH CENTRAL	
	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.	Mean	S. D.
Stature (in)	69.8	2.8	68.8	2.4	68.5	2.6	69.1	2.4	69.0	2.6	69.0	2.2	68.9	1.4
Weight (lb)	155.7	21.9	157.2	24.2	155.4	23.6	157.6	19.9	150.7	22.0	149.3	19.4	152.1	18.0
Relative weight (percent)	104.7	14.5	108.6	16.0	107.0	13.5	107.9	12.1	103.2	13.2	102.1	11.6	103.7	10.5
Fat free weight (lb)	144.9	15.5	143.7	16.0	142.6	16.3	144.8	14.0	140.4	15.6	139.0	13.9	140.8	15.0
Body fat (percent of wt)	7.0	4.1	8.0	5.9	8.0	5.3	7.6	5.0	6.4	4.6	6.4	4.5	7.0	4.6
Chest skinfold (mm)	10.0	5.4	11.2	7.5	11.4	7.1	10.8	6.2	9.3	5.7	9.5	5.5	10.1	6.0
Arm skinfold (mm)	11.5	4.5	12.8	6.2	12.5	5.4	12.4	5.4	10.8	5.0	10.8	5.0	11.6	4.6
Back skinfold (mm)	13.1	5.0	14.8	6.9	15.0	6.4	14.5	5.8	12.9	5.3	12.8	5.0	13.8	5.3
Knee skinfold (mm)	15.3	4.9	16.1	7.1	16.2	5.7	16.5	5.5	14.1	5.8	14.8	5.5	14.7	5.0
Abdomen skinfold (mm)	14.7	6.4	15.7	8.6	16.1	8.3	15.5	7.8	13.9	7.2	13.8	6.9	14.4	7.0
Number	87		328		637		231		407		254		52	

This hypothesis is difficult to reconcile with the data on Negroes shown in table 3 since there can be little question of subracial or national extraction influencing the north-south difference in body fat with this group. Several other causes are possible, such as climatic, economic, or nutritional background, and the relationships between these factors and a much larger U. S. Army series for which body weight was available have been discussed recently (Newman and Munro, '55).

SUMMARY AND CONCLUSIONS

Skinfold measurements and derived measures of body composition were obtained on a large series of young White adult males and a smaller series of young American Negro males. The limited age range and possible effects of military selection may restrict the applicability of the data for other purposes but not the internal reliability for comparisons. A racial contrast emphasized the leanness of the young Negro male and his distinctive deficiency of subcutaneous fat over the pectoral and triceps regions. Geographic grouping of the men indicated a regional difference between northerners and southerners in the amount of body fat for both Whites and Negroes. The causes of these differences in body fat are not fully clear but their relevance to human nutritional and ecological research is obvious.

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CORRELATIONS BETWEEN THICKNESS OF SKINFOLDS AND BODY DENSITY IN 88 SOLDIERS *

BY LUKE R. PASCALE, MORTON I. GROSSMAN, HARRY S. SLOANE
AND TOBY FRANKEL

*U. S. Army Medical Nutrition Laboratory, Fitzsimons Army Hospital,
Denver, Colorado*

INTRODUCTION

IT has been demonstrated that the thickness of skinfolds can be used as a quantitative criterion of leanness-fatness (Keys and Brožek, '53). Brožek and Keys ('51) have derived equations for prediction of body specific gravity from skinfold measurements. Experience in the use of these equations by this laboratory (Unpublished studies by L. R. Pascale and Medical Nutrition Laboratory, '53) indicated that the estimated body specific gravity was higher than would be expected in the groups of men studied. Refinements have been made in techniques for measurement of both skinfold thickness and body density since Brožek and Keys published their estimating equations. Calipers for measurement of skinfold thickness have been designed in which the jaw surfaces are always parallel and the spring tension is always constant regardless of the degree to which the calipers are open (Keys and Brožek, '53; Insull *et al.*, '54). One such caliper has been developed at this laboratory (Best, '53). In the measurement of body volume by underwater weighing, direct measurement of residual air volume of the lungs at the time the underwater weight is taken has been introduced and the calculations have been modified to give a more exact value of body density (Brožek *et al.*, '49; Keys and Brožek, '53).

In the present study skinfold thickness measurements were made at a number of different sites with calipers of two different designs, and the efficiency of these measurements, alone and in various combinations, in predicting body density as determined by underwater weighing was examined statistically.

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* The opinions expressed in this paper are those of the authors and do not necessarily represent those of any governmental agency.

METHODS

Subjects.

Healthy young soldiers at the post of Fitzsimons Army Hospital were used. A total of 100 men were studied, but the correlation analyses were carried out on only 88 of these, excluding non-Caucasians and men over 25 years of age. The means, ranges, and standard deviations of the ages, heights and weights of the 88 men used in the correlation analysis are presented in table 1. All subjects were fasting for at least 6 hours before the studies.

TABLE 1

Age, body weight and height of 88 subjects used in correlation analysis

	MEAN	STANDARD DEVIATION	RANGE
Age (years)	22.08	1.95	17 – 25
Body weight (kg)	68.28	11.13	49.7–109.8
Height (cm)	172.43	13.38	94 –193

Skinfold measurements.

Skinfold thickness measurements were made with both the Medical Nutrition Laboratory (MNL) and the Minnesota calipers 1953 model. The former has circular jaw faces measuring 25 mm^2 and the latter has rectangular jaw faces measuring 40 mm^2. Both calipers were calibrated so that the spring tension gave a pressure of 10 grams per square millimeter of jaw surface.

All skinfold measurements were made on the right side of the body. The skinfolds were grasped between the thumb and index finger. The span of the grasp was dependent on the thickness of the skinfold. The size of the skinfold held was great enough to include two thicknesses of skin and subcutaneous fat but not muscle or fascia. To insure against including such structures, when the measurer was in doubt he instructed the subject to perform an act which resulted in the contraction of the muscle underlying the skinfold held in the grasp. The calipers were applied about 1 cm from the fingers holding the skinfold and at a depth approximately equal to the thickness of the fold. All folds were taken in the vertical plane, except when the lines of Langer resulted in torsion of the skinfold. Then the skinfold was taken along these lines. The measurements were made of the following sites:

a. *Chest:*

  1) at the level of the xyphoid in the mid-axillary line (MAL),
  2) midpoint between the anterior crease of the axilla and the nipple,
  3) just adjacent to the nipple along the line in 2), but not to include any glandular tissue.

b. *Abdomen:*

  1) waist level
    a) at the mid-axillary line,
    b) on the extension of the mid-clavicular line;
  2) umbilicus level
    a) at the mid-axillary line,
    b) at the mid-clavicular line,
    c) adjacent to the umbilicus.

c. *Arm:* taken at the midposterior midpoint between tip of the acromion and the tip of the olecranon, determined with the elbow in 90° flexion. The skinfold measurement was taken with the extremity hanging straight in an extended position.

d. *Back:* taken at the tip of the scapula with the subject in a relaxed standing position. Here the lines of Langer usually required the fold to be taken in the diagonal plane at about 45° from the horizontal and vertical planes medially upward and laterally downward.

Body Density Determination.

The densiometric measurements were made by the use of the Archimedean principle. Subjects measured during the forenoon were fasted from 9 p.m. the night before, and those weighed during the afternoon were fasted from 6:30 a.m. the day of the examination. Each day 4 men were weighed in the morning and 4 in the afternoon period. The subjects were weighed twice during the period with at least one and one-half hours between duplicate weighings.

The apparatus consisted of a canvas waterproof tank supported by a $2\frac{1}{2}$-inch aluminum pipe frame measuring $4 \times 4 \times 6$ feet. Suspended in this tank was an aluminum, legless seat set at the bottom of a frame measuring $2\frac{1}{2} \times 2\frac{1}{2} \times 4\frac{1}{2}$ feet. The seat hung from a Detecto scale which had a capacity of 20 kilograms, with 20 gram scale divisions. The scale was suspended from a ¼ ton capacity electric hoist. The hoist was attached to a steel I-beam 13 feet above the floor level.

Attached to the frame of the seat was a respiratory "T" valve for controlling the source of inspired gas. One opening of the three was connected to a rubber mouthpiece, the second to a "snorkel" tube and the third to a source of approximately 99.7% oxygen and 0.3% inert gas (known exactly for each tank). The valve was arranged so that the mouth would be connected to only one of the gas sources at any time. A respiratory flutter valve was attached to the opening for oxygen supply. This allowed oxygen to enter from the delivery side of the valve during inspiration and restricted the backflow during expiration causing a forward flow of the expired air to a collecting Tissot spirometer.

Each subject immediately before being tested emptied his urinary bladder. He was then weighed to the nearest 10 grams in air on a Plima beam balance and was placed in the aluminum seat. The mouthpiece was put in his mouth and the airway connected to room air by means of the "snorkel" tube. The oxygen delivery and collecting system was flushed repeatedly with tank gas to insure that this gas was throughout the system. The nostrils were occluded completely with a nose clip. The water in the tank was kept between 32–36° C. The subjects were instructed to take in an average breath, the seat was lowered, and when the descent stopped they exhaled in a steady continuous forcible fashion to express all the air possible from their lungs. At the end of exhalation the tongue was inserted into the mouthpiece in order completely to occlude the opening. At this time the scale was released and the underwater weight was taken to the closest 20 grams. These weighings were repeated several times to get the maximal underwater weight and the minimal residual lung volume. With the subject adequately conditioned the final weight was taken as the weight for the calculation of the body density. At this time, with the mouthpiece still occluded, the respiratory valve was turned to the oxygen delivery line and the subject was then brought out of the water and allowed to breathe quietly for 7 minutes. All exhaled air was collected during this time and at the end of the collection period the valve was closed to the line and 3–5 liters of oxygen flushed through. The volume and temperature of the expired gas was taken after the gas had been mixed for 3 minutes. The gas was then stored in mercury filled gas sampling bulbs before analysis. At the end of each test the tare weight of the scale and water temperature were taken.

The nitrogen content of the expired gas was analyzed in the Van Slyke apparatus using the method of Van Slyke and Sendroy ('32).

The residual lung volume was calculated by the method of Cournand *et al.* ('41).

The body density was computed by the method of Keys and Brožek ('53).

Both the skinfold thickness measurements and the body density determinations were done in duplicate several hours apart.

Relative body weight was calculated from the values of the Medico-Actuarial tables as given by Davenport ('23).

TABLE 2

First order correlation coefficients between body density and skinfold thicknesses at various sites measured with two types of calipers

SITE	REGION	CALIPER USED FOR MEASUREMENT MNL	MINN. (1953 model)
	A. Chest		
a	1. mid-axillary line (MAL) at xyphoid	—.8281	—.8173
b	2. midpoint between anterior crease of axilla and nipple	—.7889	—.7992
c	3. juxta nipple	—.8251	—.8101
	B. Abdomen		
	1. waist level		
d	a. mid-axillary line	—.7383	—.6877
e	b. mid-clavicular line	—.7308	—.7077
	2. umbilicus level		
f	a. mid-axillary line	—.7129	—.6983
g	b. mid-clavicular line	—.7203	—.7030
h	c. adjacent to umbilicus	—.7703	—.7593
i	C. Arm	—.7713	—.7513
j	D. Back	—.7397	—.7046

RESULTS

The precision of the density measurements was estimated from the duplicate determinations by the method of Youden ('51) where S. D. $= \sqrt{\frac{\Sigma d^2}{2n}}$, where S. D. is the standard deviation of a single deter-

TABLE 3

Percentile distribution of relative body weight, density and skinfold thicknesses

($N = 88$)

CRITERION	PERCENTILES				MEDIAN	MEAN	S. D.
	20	40	60	80	50		
Relative body weight	90.04	95.37	101.33	108.17	97.82	100.71	13.37
Body density	1.0579	1.0657	1.0718	1.0771	1.0694	1.0678	.0120
Skinfolds (cm):							
Chest, MAL xyphoid	.59	.79	.96	1.21	.85	1.04	.60
Chest, juxta nipple	.78	1.02	1.23	1.60	1.15	1.36	.79
Abdomen, umbilicus level	.96	1.27	1.60	2.03	1.42	1.64	.88
Arm	.83	1.02	1.25	1.49	1.10	1.21	.46
Back	.88	1.04	1.18	1.47	1.08	1.22	.50

mination, *d* is the difference between duplicate determinations and *n* is the number of pairs of determinations. This gave a value of 0.0024 which is comparable to the values reported by Keys and Brožek ('53).

Table 2 presents the first order correlation coefficients between body density and skinfold thickness at various sites measured with the two different calipers. In all but one instance (site b) the correlation coefficient is higher for the measurements made with the MNL caliper than for those made with the Minnesota caliper. All further correlation analyses were performed only on the values for the MNL calipers. Those sites which showed the highest correlation coefficients for each area of the body were used for subsequent multiple regression analyses (sites a, c, h, i and j).

TABLE 4

Frequency distribution of body density values
($N = 88$)

BODY DENSITY CLASS INTERVAL	MEN	FREQUENCY %	CUMULATIVE %
1.020–1.029	1	1.1364	100.0000
1.030–1.039	3	3.4091	98.8636
1.040–1.049	3	3.4091	95.4545
1.050–1.059	12	13.6364	92.0454
1.060–1.069	28	31.8182	78.4090
1.070–1.079	28	31.8182	45.5908
1.080–1.089	13	14.7727	14.7727

The distribution of body density, skinfold thicknesses and relative body weight by percentiles is presented in table 3 together with the means and standard deviations for these values. Table 4 gives the frequency distribution of the body density values.

Table 5 presents the prediction equations for estimation of body density from individual skinfolds and relative body weight. In table 6 the forecasting efficiency (F. E.) and standard errors of estimate for these same criteria of leanness-fatness are given.

Multiple regression analysis was performed by the method of Doolittle (cited by Johnson, '49). The intercorrelations between the various indices of leanness-fatness appear in table 7. Using these 6 variables the following multiple regression equation was obtained:

$$\hat{Y} = 1.080120 - .012031X_1 - .005775X_2 + .000004X_3 - .007113X_4 + .007549X_5 + .007416X_6 \qquad (1)$$

TABLE 5

Equations for prediction of body density ($\hat{Y} = a + bX$) on the basis of single factor criteria. (Skinfold values are in cm)

VARIATE	
Skinfolds:	
Chest, MAL xyphoid	$1.0849 - .0164X_1$
Chest, juxta nipple	$1.0849 - .0126X_2$
Abdomen, umbilicus level	$1.0851 - .0105X_3$
Arm	$1.0923 - .0202X_4$
Back	$1.0896 - .0179X_5$
Relative body weight	$1.1251 - .0569X_6$

TABLE 6

Coefficients of correlation (r) between body density and other criteria of fatness-leanness, indices of forecasting efficiency (F. E.), and standard errors of estimate of the body density (S. E. E.)

VARIATE	r	F. E.	S. E. E.
Skinfolds:			
Chest, MAL xyphoid	—.8281	43.9	.0067
Chest, juxta nipple	—.8251	43.5	.0068
Abdomen, umbilicus level	—.7703	36.2	.0077
Arm	—.7713	36.4	.0076
Back	—.7397	32.7	.0081
Relative body weight	—.6342	22.7	.0093

$$\text{F. E.} = 100(1 - \sqrt{1 - r^2})$$

$$\text{S. E. E.} = SD_y\sqrt{1 - r^2}$$

The coefficient of multiple correlation between density and the 6 prediction variables was $R = 0.8609$. The standard error of estimate was 0.00636 and index of prediction efficiency was 49.1%. Those variables that did not contribute significantly to the accuracy of predictions were deleted, giving the following equation:

$$\hat{Y} = 1.088468 - .007123X_1 - .004834X_2 - .005513X_4$$

for which $R = 0.8495$, standard error of estimate $= 0.00648$ and F. E. $= 47.3\%$.

TABLE 7

Intercorrelations between indices of fatness ($N = 88$)

Where Y = Body Density
X_1 = Chest, MAL xyphoid
X_2 = Chest, juxta nipple
X_3 = Abdomen, umbilicus level
X_4 = Arm
X_5 = Back
X_6 = Relative body weight

	X_6	X_5	X_4	X_3	X_2	X_1
Body Density (Y)	—.634149	—.739663	—.771324	—.770310	—.825134	—.828078
Skinfolds						
X_1	.806303	.923470	.828742	.902424	.927314	
X_2	.766231	.890953	.829112	.895559		
X_3	.802624	.837442	.778346			
X_4	.730315	.821973				
X_5	.835712					

Figure 1 is a scatter-diagram of the individual values for chest skinfold thickness (mid-axillary line at the level of the xyphoid) and body density.

DISCUSSION

It was hoped that the use of improved methods for the determination of body density and skinfold thicknesses would lead to more efficient prediction equations. This did not occur. Comparing our results with those of Brožek and Keys ('51) the following criteria of prediction efficiency are obtained (using the 3 variable equation in each instance):

	R	S. E. E.	F. E.
MNL	0.8496	0.00648	47.3%
Brožek and Keys	0.8709	0.00722	50.9%

It should be noted, however, that the skinfold sites represented by these two analyses are not the same. Chest and arm skinfolds were used in both, but in the study of Brožek and Keys the third site was the abdomen whereas in the present study the relative efficiency of the various sites dictated the use of the fold at the level of the xyphoid in the mid-axillary line as the third site.

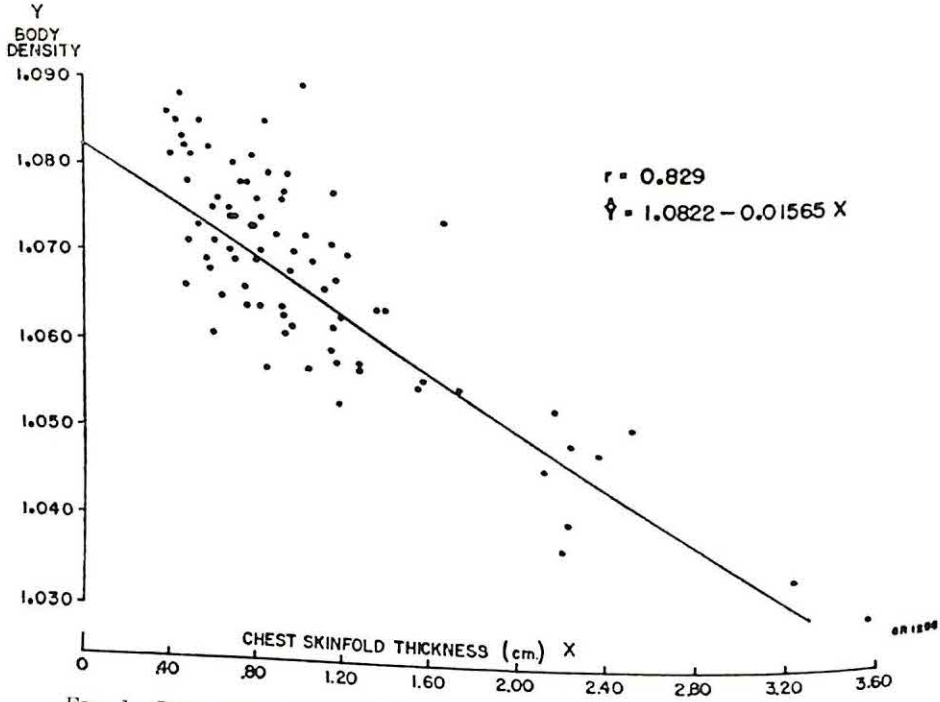

FIG. 1. RELATION BETWEEN BODY DENSITY AND THICKNESS OF CHEST SKINFOLD IN 88 YOUNG MEN.

Substituting the mean values of the present study for the indicated skinfold thicknesses of the equation of Brožek and Keys (their equation No. 3) we obtain an estimated mean specific gravity of 1.0764. Assuming that the measurements were made in water at 35 to 36° C ($d = 0.994$), this would correspond to a density of 1.0699 whereas the observed mean density was 1.0678. This confirms our impression that with the skinfold thickness values obtained from the calipers in current use (including the Minnesota 1953 design), the estimation of specific gravity by the Brožek-Keys equation gives for young soldiers values that are too high.*

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* Editor's Note: The equation was derived for skinfold calipers with a pressure of about 35 gm/mm^2 (Minn. model 1948). A correction for pressure would have increased the difference.

One of the objects of this study was to determine which sites for skinfold thickness measurement on the chest and abdomen have the greatest power in predicting body density. Brožek *et al.* ('54) have shown that there is a considerable gradient of skinfold thickness as the site of measurement moves from the nipple or the umbilicus. Exact definition of the site of measurement therefore assumes importance both in terms of reproducibility of measurements and in terms of prediction efficiency. Using the first order correlation coefficients as indices of prediction efficiency it will be seen from table 2 that on the chest the site immediately adjacent to the nipple (site c) is superior to the site at the mid-point between the nipple and the anterior axillary fold (site b). In addition, the site in the mid-axillary line at the level of the xyphoid has the highest r value of any of the sites measured in this study and, since it is relatively far removed from the juxta-nipple site, it was retained as one of the sites used in the regression analyses. On the abdomen the site adjacent to the umbilicus proved to have the highest r value (site h, table 2).

SUMMARY AND CONCLUSIONS

In 88 healthy young soldiers (mean age 22.1 years), skinfold measurement were made at a variety of sites; body density was measured by underwater weighing. Using only those sites of skinfold thickness measurement which contributed significantly to the prediction efficiency, the following multiple regression equation was derived:

$$\hat{Y} = 1.088468 - .007123X_1 - .004834X_2 - .005513X_4$$

where Y is estimated body density, X_1, X_2 and X_4 are skinfold thicknesses in centimeters taken respectively at the chest in the mid-axillary line at the level of the xyphoid, at the chest in the juxta-nipple position, and on the dorsum of the arm at the midpoint between the tip of the acromion and the tip of the olecranon. The multiple regression coefficient, R, for this equation was 0.85 and the standard error of estimate was 0.0065 body density units.

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THE CANADIAN WEIGHT-HEIGHT SURVEY

BY L. B. PETT AND G. F. OGILVIE
Nutrition Division, Department of National Health and Welfare
Ottawa, Canada

THE standard of living and way of life of Canadians is similar in many respect to that of citizens of the United States. Both population groups are endowed with an abundance of foodstuffs and are therefore exposed to the hazards of overnutrition. Before launching or endorsing a campaign against overweight in Canada, a critical study was made of the standards for weight and the criteria used to diagnose obesity. Many sets of tables were in use as "standards" but none had the valid mathematical basis that was desired. Confusion existed over the definition of "overweight" and "obesity" and no objective data were available on different body types.

Although no one seriously questions the evidence that many degenerative diseases are more prevalent among overweight people, it is not clear whether the villain is body weight itself or fat metabolism. The questions of total fat content of the diet and of various fat fractions in the blood were scrutinized. The possibility that people who have lost weight and then regained some or all of it back may develop more severe hypertension than if they had never reduced was a further deterrent to hasty propaganda.[1] The high percentage of relapses in weight control programs and the mental health aspects must also be considered.

It was an opportune moment in Canada to undertake an anthropometric study of the population, as recommended in the Second FAO/WHO Nutrition report of 1952. The results of the 1951 census had just become available and the Dominion Bureau of Statistics agreed to provide a sampling plan based on methods used for many years in sampling the Labour Force. The object was to obtain a representative sample of the entire population on which height and weight measurement could be made. From these data, tables of average weight for height, age and sex could be constructed, which would indicate the situation as it actually existed and provide a base line from which further and more complete studies could be started.

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[1] *Cf.* J. Brožek, C. B. Chapman and A. Keys, 1948, Drastic food restriction: Effect on cardiovascular dynamics. J. Am. Med. Assoc., *137*: 1569-1574.

METHOD AND EQUIPMENT

The sample was selected by an area stratification plan, proportionate to population density. The entire country was divided into primary sampling units, each of which had a dominant characteristic such as a particular industry, type of farming, soil type, climate, national extraction or others. All sampling units with similar basic characteristics were grouped together into a stratum and one or more units were selected by random procedure to represent all the units in the stratum. These units were not necessarily of equal size nor were they contiguous, but the randomization gave each Canadian an equal chance of being included in the sample.

This process yielded 59 units in which to make measurements, 13 of which were metropolitan. The non-metropolitan units were subdivided into urban, rural non-farm and rural farm areas for further random selection according to the number of persons to be measured. In the metropolitan areas a selection of city blocks was used. In each area approximately 0.1% of the population of the stratum was examined because this figure gave about 400 individuals in each sex and age group of the final table planned. It must be emphasized that the plan was drawn up according to resources available, *e.g.*, by grouping certain ages, in a manner that would not affect the random nature of the sampling. Large scale maps of each area were obtained and the specified number of households were selected from lists of census visitation records. Thus the sample was located geographically and, to a considerable extent, pinpointed on maps.

Since it was not possible to pre-determine the age of each person to be visited, it was decided that a suitable dispersion of ages would result from combining three different sources:

1. Schools where all children between 5 and 16 years could be located and visited according to the necessary ratio.

2. Business establishments employing 15 or more persons, an arbitrary category used because records of such establishments are available in lists from which random selection could be made.

3. Households where housewives, pre-school children, older persons, and others not covered above could be reached.

Excluded were those confined to bed through illness, pregnant women, children under two years, Armed Service personnel in camp or barracks, Indians on reserves, and certain classes of cripples and invalids. Allowances were made for non-interviews and these amounted to about 20% for all reasons. In a few areas, special efforts to sample this 20% yielded data that suggest no difference in averages from the main sample.

The task of weighing and measuring the persons selected in this widely scattered sample was undertaken only after careful preparations had been made. The selection of suitable equipment, the training of field workers and a standardized recording and reporting procedure were all important considerations.

The nature of the survey demanded that the equipment be readily portable and rugged enough to withstand severe handling. The biggest problem proved to be the selection of scales. Many types of scales were considered and those finally selected were a spring type with a circular dial and moving needle that could be read to the nearest ½ pound from any angle. This feature minimized the error due to parallax. The scales were checked at frequent intervals for accuracy, using standard weights. The measuring rod was of the collapsible telescopic type with a horizontal cross-bar. Height measurements were made to the nearest ¼ inch with the subject standing in a normal upright position, but without drawing up to his greatest height by pressing against a solid wall. The skinfold calipers were designed and manufactured in the Laboratory of Physiological Hygiene at the University of Minnesota. These calipers contained a constant tension device (10 grams per sq mm) and measured over a constant area of skin (40 sq mm). Readings were made to the nearest millimeter. Difficulties in obtaining the necessary instruments in time prevented the use of the metric system in recording weights and heights.

It was felt that a small number of thoroughly trained field workers would be preferable to a large number of part time workers. For this reason, the nutritionists and nurses on the regular staff of this Nutrition Division were assigned to the job of collecting the data. They were all experienced in interview technique and could readily adapt themselves to this new work.

To formulate a standardized procedure for obtaining the data, a pilot study was undertaken in an Ottawa suburb. The many difficulties that arose were discussed and ironed out and it was at this point that we decided to limit the number of measurements taken to what seemed feasible with a minimum of refusals. For example, the site of the skinfold measurement was confined to the back of the upper arm and we dispensed with sitting height and other possible measurements because they were too difficult to obtain under the conditions of the present study. The precise sampling method demanded that the highest possible yield be obtained, and to achieve this, the cooperation of the public was essential. This fact was impressed on each field worker and they managed to keep the non-interview rate at a low figure.

The examiners worked alone or in pairs and travelled to all 59 sampling areas across the country. They usually obtained the help of a local person from a health unit or district census office to act as a driver and guide. The cooperation of the local Medical Officer of Health was obtained and an advance letter explaining the purpose of the survey and signed by the Medical Officer was sent to each participating household. This association with a familiar name and local letterhead had a reassuring effect on most householders and greatly simplified the work of the field worker in introducing herself.

Participants were weighed and measured and the skinfold measurement obtained while in usual indoor clothing *but with shoes removed.* The examiner then inquired the relationship to the head of the household and the month and year of birth. Our earlier investigation had revealed that people were more willing to state their year of birth than their age. The age in years was later calculated and recorded on the work sheets by the clerical staff, thus avoiding mental arithmetic on the spot.

The data sheets were returned daily to the central office for tabulating. As it was impossible to predetermine the ages of all persons falling in the sample, the cumulative totals for each age group were posted daily to detect any abnormalities in the dispersion of age groups. This method of control revealed that the sample provided a fairly good distribution of ages, with the exception of pre-school children, who for some unexplained reason, failed to appear in the expected numbers in the households visited. This group was subsequently dropped from the final table.

The field work began in March, 1953, and continued until October of that year. During that time, more than 22,000 Canadians were weighed and measured. The field workers visited many remote localities and used every conceivable means of transport to trace the randomly selected persons on their lists. They succeeded in weighing and measuring over 80% of the original sample. This yield was considered by the statisticians to be adequate. Throughout the survey, consultations were held with sampling experts at the Dominion Bureau of Statistics. By eliminating bias in every possible way from the sample design, and by reducing personal and mechanical errors through special training and frequent inspection, stress was laid on the quality of the data. In this survey, quality was considered more important than sheer weight of numbers.

RESULTS

At the conclusion of the field work, the entire bulk of the raw data was turned over to the Dominion Bureau of Statistics for processing. A special punch card was designed, on which all details could be transcribed from the work sheets. The first step was to group the measurements into intervals of one inch and one pound. This was achieved by moving the ¼ inch figures down, the ¾ inch figures up and the ½ inch alternately up and down as the cards were sorted. The ½ pound figures were moved alternately up and down. A weighting factor was assigned to each person's measurements. This factor was calculated from the ratio of the sample to the total population in the sampling area.

The heights and weights reported are on individuals dressed in indoor clothing but with shoes removed. If weights are to be expressed as nude weights, a downward adjustment must be made on the figures in the table. The weight of men's clothing varied between 2 and 3 pounds, depending on the amount and type of textile in their attire. The uniformity of men's dress during the period of measurement (*i.e.*, shirt, trousers and underclothing) reduced the weight variation to a limit of one pound. With women, a wide variation in mode of dress was observed. In fact, it would be hazardous to speculate on the weight of impedimenta concealed on the more obese women. However, an average adjustment of 2 to 3 pounds could be made for women's indoor clothing. In children, the variation was greatest of all and varied from 1 to 3 pounds, depending on the size of the child.

The completed punch cards were run through a series of sortings on mechanical tabulating and calculating machines. These calculations resulted in a series of tables showing the weighted mean height, weight and skinfold for each age group and sex (table 1) and the average weight for each inch of height, age and sex (table 2) and percentile distributions (tables 3 to 5).

TABLE 1

Canadian average height, weight (in ordinary indoor clothing, without shoes), and skinfold by age and sex (1953 data)

AGE GROUP YEARS	SEX	AVERAGE HEIGHT (in)	(cm)	AVERAGE WEIGHT (lb)	(kg)	AVERAGE SKINFOLD (mm)
2	M	34.7	88.1	30	13.6	9.4
	F	33.6	85.3	28	12.7	9.5
3	M	36.6	93.0	32	14.5	9.0
	F	36.0	91.4	31	14.1	9.6
4	M	39.2	99.6	37	16.8	8.3
	F	39.2	99.6	36	16.3	9.3
5	M	41.9	106.4	40	18.1	7.5
	F	41.8	106.2	41	18.6	8.8
6	M	44.6	113.3	46	20.9	7.4
	F	44.2	112.3	44	20.0	8.8
7	M	47.0	119.4	50	22.7	6.9
	F	46.5	118.1	49	22.2	8.5
8	M	49.1	124.7	57	25.9	6.8
	F	48.9	124.2	57	25.9	8.9
9	M	51.3	130.3	63	28.6	7.1
	F	51.0	129.5	62	28.1	9.4
10	M	53.5	135.9	70	31.8	7.4
	F	53.3	135.4	69	31.3	9.5
11	M	55.4	140.7	77	34.9	7.9
	F	55.3	140.5	77	34.9	10.0
12	M	57.4	145.8	84	38.1	8.0
	F	58.2	147.8	92	41.7	10.5
13	M	59.3	150.6	94	42.6	8.3
	F	60.4	153.4	102	46.3	11.2
14	M	62.2	158.0	108	49.0	7.5
	F	61.3	155.7	107	48.5	11.3
15	M	64.7	164.3	119	54.0	6.5
	F	62.2	158.0	112	50.8	11.3
16–17	M	66.7	169.4	136	61.7	6.4
	F	62.5	158.8	120	54.4	13.3
18–19	M	68.0	172.7	144	65.3	6.0
	F	62.6	159.0	124	56.2	13.6
20–24	M	67.9	172.5	154	69.9	6.3
	F	62.8	159.5	124	56.2	12.4
25–29	M	68.3	173.5	160	72.6	7.0
	F	62.7	159.3	126	57.2	13.0
30–34	M	68.0	172.7	167	75.7	8.2
	F	62.8	159.5	130	59.0	14.3
35–44	M	67.5	171.4	167	75.7	7.7
	F	62.4	158.5	135	61.2	15.5
45–54	M	66.9	169.9	164	74.4	7.5
	F	61.8	157.0	144	65.3	17.7
55–64	M	66.0	167.6	161	73.0	6.9
	F	61.3	155.7	147	66.7	17.7
65 and over	M	65.4	166.4	155	70.3	5.6
	F	60.6	153.9	138	62.6	15.5

TABLE 2

Canadian average weights for height and age (in ordinary indoor clothing, without shoes)

For young adults, the average (mean) weight at a given height is probably the weight desirable for health. After the age of 30 years most people should maintain their weight below the figure in the table. Variation in body types may account for differences up to 10% above or below the weight at a given height.

MEN

HEIGHT IN FEET-INCHES		AGE IN YEARS 15	16–17	18–19	20–24	25–29	30–34	35–44	45–54	55–64	65 AND OVER
4′	9″	83									
	10	88									
	11	92	99	116	121	128	134	135	127	138	126
5	0	97	103	119	124	132	138	139	132	141	130
	1	102	108	122	127	135	141	142	136	144	135
	2	106	113	125	131	139	145	146	141	148	140
	3	111	118	128	134	142	148	150	146	151	144
	4	116	122	131	138	146	152	153	150	154	149
	5	121	127	134	142	149	156	157	155	157	154
	6	125	132	138	145	153	159	161	160	160	158
	7	130	136	141	149	156	163	164	165	163	163
	8	135	141	144	152	160	166	168	169	166	167
	9	139	146	147	156	163	170	172	174	169	172
	10	144	151	150	159	167	173	175	179	172	177
	11	148	155	153	163	170	177	179	183	176	181
6	0	153	160	156	166	174	181	183	188	179	186
	1	158	165	160	170	177	184	186	193	182	191
	2	163	169	163	173	181	188	190	197	185	195
	3	167	174	166	177	184	191	194	202	188	200

WOMEN

HEIGHT IN FEET-INCHES		AGE IN YEARS 15	16–17	18–19	20–24	25–29	30–34	35–44	45–54	55–64	65 AND OVER
4′	8″	96	105	100	106	110	115	126	130	134	120
	9	99	107	103	108	112	117	127	132	137	124
	10	101	110	107	111	114	119	128	134	139	128
	11	104	112	110	113	117	122	130	137	141	132
5	0	107	115	114	116	119	124	131	139	144	136
	1	109	117	118	118	122	126	133	142	146	140
	2	112	120	121	121	124	129	134	144	148	144
	3	115	122	125	123	127	131	135	146	151	148
	4	117	125	129	126	129	133	137	149	153	152
	5	120	127	132	128	132	136	138	151	155	157
	6	123	130	136	131	134	138	140	153	158	161
	7	126	132	140	133	137	140	141	156	160	165
	8	128	135	143	136	139	143	143	158	162	169
	9	131	137	147	138	141	145	144	160	165	173
	10	134	140	151	141	144	147	145	163	167	177
	11	136	142	154	143	146	150	147	165	169	181

TABLE 3

Canadian height and weight survey
Percentiles of height (in centimeters) by age and sex

AGE GROUP YEARS	SEX	P_{25}	P_{50}	P_{75}
2	M+F	83.1	86.6	89.9
3	M+F	88.6	91.7	95.2
4	M+F	96.5	99.6	103.4
5	M+F	103.1	106.9	110.5
6	M+F	109.2	113.3	116.3
7	M	114.8	118.9	122.9
	F	114.3	118.4	121.9
8	M	120.9	124.5	128.3
	F	119.2	124.2	128.3
9	M	126.2	130.3	134.9
	F	125.5	129.0	133.9
10	M	130.8	135.4	140.5
	F	130.3	134.9	139.7
11	M	135.4	140.5	145.8
	F	134.6	140.5	145.5
12	M	140.2	145.3	150.9
	F	142.0	148.1	153.2
13	M	144.5	150.1	156.7
	F	149.1	153.7	158.2
14	M	151.1	158.0	165.1
	F	149.9	155.7	160.5
15	M	158.0	165.1	171.2
	F	153.4	158.0	162.6
16–17	M	167.9	171.7	176.8
	F	154.4	159.0	163.1
18–19	M	168.4	173.2	176.8
	F	155.2	159.3	162.8
20–24	M	168.1	173.5	177.3
	F	155.2	159.8	163.6
25–29	M	167.9	173.5	179.6
	F	154.7	159.0	163.1
30–34	M	168.1	173.0	178.1
	F	155.2	159.0	163.3
35–44	M	166.9	171.7	177.3
	F	154.2	158.5	162.6
45–54	M	164.6	169.7	175.3
	F	152.9	157.0	160.5
55–64	M	162.1	167.6	173.2
	F	151.6	154.9	159.5
65 and over	M	161.0	165.4	170.7
	F	149.6	153.9	158.2

TABLE 4

Canadian height and weight survey
Percentiles of weight (in kilograms) by age and sex

AGE GROUP YEARS	SEX	P_{25}	P_{50}	P_{75}
2	M+F	12.1	13.2	14.2
3	M+F	13.0	14.2	15.5
4	M+F	15.2	16.5	17.6
5	M+F	16.7	17.8	19.9
6	M+F	18.5	20.2	22.0
7	M	20.6	22.6	24.6
	F	19.7	21.9	24.4
8	M	23.0	25.4	27.7
	F	22.1	24.5	27.8
9	M	25.7	28.2	30.9
	F	23.8	27.2	31.2
10	M	27.8	30.8	34.5
	F	27.3	30.3	34.2
11	M	30.6	33.9	38.0
	F	29.6	33.3	39.0
12	M	33.3	37.0	42.0
	F	34.8	40.5	46.6
13	M	36.6	41.3	46.8
	F	40.7	46.4	50.5
14	M	41.9	47.9	54.3
	F	42.3	47.4	53.7
15	M	45.9	53.9	60.9
	F	45.2	50.0	55.8
16–17	M	56.2	61.4	67.4
	F	48.9	54.6	59.3
18–19	M	59.1	63.7	71.1
	F	50.7	54.6	59.2
20–24	M	63.6	68.3	73.9
	F	50.2	55.2	60.9
25–29	M	65.5	71.3	79.9
	F	50.5	56.0	61.8
30–34	M	67.5	76.1	82.0
	F	51.6	57.0	64.9
35–44	M	67.6	74.9	82.8
	F	54.5	59.9	66.3
45–54	M	65.5	73.0	82.1
	F	56.4	64.3	72.8
55–64	M	64.8	72.1	79.4
	F	58.2	65.8	75.2
65 and over	M	61.1	70.6	78.2
	F	54.4	61.5	69.3

TABLE 5

Canadian height and weight survey
Percentiles of skinfold (in millimeters) by age and sex

AGE GROUP YEARS	SEX	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}
2	M+F		7.8	9.4	10.7	
3	M+F		7.6	9.1	11.0	
4	M+F		7.2	8.5	10.2	
5	M+F		6.3	7.7	9.6	
6	M+F		6.1	7.6	9.4	
7	M	4.2	5.1	6.4	8.1	9.8
	F	5.5	6.6	8.0	9.7	12.1
8	M	4.2	5.1	6.4	8.1	9.6
	F	5.5	6.6	8.5	10.5	12.9
9	M	4.3	5.1	6.4	8.1	10.4
	F	5.6	6.9	8.5	11.0	14.6
10	M	4.4	5.2	6.7	8.4	11.3
	F	5.3	6.8	8.6	11.0	14.6
11	M	4.2	5.4	7.0	9.2	12.3
	F	5.4	7.0	9.1	12.0	15.4
12	M	4.2	5.2	6.9	9.7	12.5
	F	5.7	7.1	8.9	12.4	18.1
13	M	4.1	5.3	6.7	9.5	13.9
	F	5.9	7.5	10.0	13.8	17.3
14	M	3.7	4.6	6.2	8.4	13.0
	F	5.8	7.8	10.7	13.4	17.4
15	M	3.4	4.4	5.4	7.8	10.5
	F	6.2	7.9	10.2	14.3	17.5
16–17	M	3.2	4.0	5.2	7.8	10.9
	F	7.0	9.5	13.1	16.4	20.2
18–19	M	3.1	4.0	5.3	6.9	9.5
	F	6.8	9.6	13.1	17.3	20.1
20–24	M	3.2	4.0	5.3	7.5	10.4
	F	5.9	8.0	11.2	15.3	19.8
25–29	M	3.3	4.4	5.8	8.8	11.5
	F	6.1	8.3	11.7	16.3	21.5
30–34	M	3.4	4.7	7.3	10.1	14.4
	F	6.6	8.4	12.7	18.1	24.9
35–44	M	3.4	4.8	7.0	9.8	13.1
	F	7.7	10.2	14.4	20.2	24.8
45–54	M	3.1	4.2	6.6	9.9	13.7
	F	9.1	11.8	17.5	22.4	26.8
55–64	M	2.9	4.0	5.6	8.2	12.9
	F	9.9	12.9	17.0	21.7	28.0
65 and over	M	2.6	3.3	4.4	6.5	10.5
	F	6.5	10.1	14.3	20.2	25.0

To extend the height-weight figures to the extremes of height where real data were lacking or limited, it became necessary to establish curves for height and weight in each age group, using the methods of least squares and three moving averages. No attempt was made in table 2 to smooth the differences in weight at any given height in the various age groups.[2] Reading the table vertically, there is naturally a weight increment with increasing height, but horizontally there are variations up and down with increasing age which may have a physiological basis—for example, the decrease in average weights for men over 65 years of age may be the result of increased mortality in those who are overweight, especially at shorter heights. These are problems which require further investigation, and which we intend to pursue.

What is a proper interpretation of these figures? Are they "ideal" or "desirable"? The first answer is that the new Canadian averages provide a standard or reference point that is much clearer in its derivation and significance for the population than any previous figures.

No figure for weight can ever be used as an absolute standard. Some variation is permitted. One widely used insurance table lists weights for three types of body "frame" at each height, but without defining "frame"; it then lists two figures under each type without advice on when to use the lower, and when the higher figure. This presentation has been useful to allow some latitude in each category, but to use it properly would require definitions and judgment. Similar approach has been used in referring to tables giving a single weight, presumably "ideal"; it is customary to allow 5, 10 or even 20% of the figure given, above or below, according to the purpose in mind.

Such adjustments can be applied to the new table of Canadian average weights, with the added advantage that the starting point has a clear relationship to the population, and is therefore much better than figures derived in unknown ways or from limited groups. Thus if the specialist considers that diabetic patients should maintain weight 10% below the average, it is just as easy for him to refer to the Canadian weight standard as to use any other yardstick. He has the additional information that more than half the people in the particular age-sex-height group weigh more than the weight he has selected (10% below the figure in this table). Conversely, if a person asks a physician whether she must gain weight up to the figure in the table of averages, he has an excellent opportunity to explain that an average is a kind of mid-point, with many people normally below and above.

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[2] Editor's Note: For actual use *smoothed* values would be preferable. This would eliminate "accidental," unsystematic ups and downs, without affecting the age trends.

Is a person overweight if he or she is above average? They may be. There is increasing evidence that "overweight" by itself, as judged in older tables by the use of 10 or 20% limits, is not as significant in the big killers like cardiovascular-renal disease as combining a consideration of weight with a measurement of subcutaneous tissue (the skinfold measurement). The combined measurements will provide a research tool for much better evaluation of patients than arbitrary percentages of "average weights" taken from tables of uncertain origin or validity.

ANTHROPOMETRY AND NUTRITIONAL STATUS OF ADULT WOMEN[1]

BY MARGARET A. OHLSON,[2] ALICE BIESTER,[3] W. D. BREWER,[2]
BETTY E. HAWTHORNE[2] AND MARIE BOHLAND HUTCHINSON[3]

FEW studies of the anthropometry of living adult women have appeared in the literature and none of these include significant numbers of subjects in the upper age brackets.

The measurements presented in this paper were made as a part of an extended investigation into the nutritional status of women. The study was initiated in 1935 as a regional project of the agricultural experiment stations of the North Central states. Five of the groups cooperated in the measurement of 1013 freshman college women aged 17 to 21 years (Donelson *et al.*, '40). This study provides a point of reference for evaluating the present series since the subjects were from the same geographical areas and common techniques were used. In 1947, a second regional project was organized to collect similar data on the nutritional status of adult women living in their own homes. Particular effort was made to include women more than 50 years of age. Anthropometric measurements made at the Michigan and Minnesota stations form the basis of this report.

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[2] Michigan State University, East Lansing.

[3] University of Minnesota, St. Paul.

SUBJECTS

The subjects measured represent a limited sample, and the women from the two states may not be compared directly. Women measured in Minnesota came from Census Tract 1 in St. Paul, which is adjacent to the St. Paul campus of the University of Minnesota, with the exception of those above 80 who lived in the larger metropolitan area in which St. Paul and Minneapolis are located. The heads of three fifths of the households were professional or semi-professional workers; about one sixth were retired. The plan used in selecting the sample was devised with the help of the Department of Agricultural Economics. All women were of sufficient health and vigor to be brought to the laboratory for an extensive series of tests as well as the anthropometric measurements.

In Michigan, an area sample of women living within the metropolitan limits of Lansing and East Lansing was chosen. One hundred and four white women were interviewed in their homes and 40 of them were persuaded to come to the college laboratories for measurements and other physical and physiological tests. Because health and mobility determined, to a degree, the capacity of the women to participate, a large proportion of the physically infirm included in the original interviews were eliminated. However, selection did not change the character of the sample with respect to the distribution of women within the various economic and sociological groups. The area included is that of an industrial city and a wealthy industrial suburb.

The Michigan sample of Negro women represents an attempt to obtain an area sample of a limited housing district in an industrial city. The 102 women interviewed were of higher social status than is believed characteristic of the Negro community as a whole since the women of lesser social poise either refused to be interviewed or gave such unsatisfactory information that the interviews were discarded. Fifty of the Negro subjects came to the college to be measured.

The third series of Michigan women represents selected subjects studied as a part of a project on weight reduction.

EXPERIMENTAL METHODS

The techniques of measurement used are those described by Hrdlička in 1920 except as will be noted. Measurements chosen (stature, weight, transverse and antero-posterior diameter of chest, bi-iliac and bi-trochanter width, girth of the upper arm at the point just below the insertion of the deltoid muscle and maximum calf girth) were thought to reflect nutrition and to be influenced to only a minor degree by temporary changes in hydration.[4]

Stature was measured on a platform with a rigid vertical upright to which a measuring tape was attached. The upright was 72 inches high and of the same width as the platform thus forming a solid support for the back. The subject was required to stand with the feet parallel, heels, buttocks and shoulders touching the upright and head held comfortably erect. A hardwood square in contact with the upright was brought down to touch the subject's head. Preliminary testing demonstrated that height could be measured by different investigators and at different times of the day with minimum variation with this technique as compared with the variations obtained without the back support.

Weight was determined with clothing weighing less than a pound and was not corrected for the weight of clothing. A Fairbanks balance was used and weight recorded to 0.01 kg. Measurements of width and girth were made with a standard metal caliper[5] and a steel tape calibrated in tenths of a centimeter.

RESULTS

The measurements, with standard deviations, of Michigan and Minnesota White women are given in table 1. College subjects from the earlier study from Ohio and Minnesota are included as Michigan college women were not studied in the earlier work. Michigan women for each age group are shorter, heavier, and larger than Minnesota women in each of the width and girth measurements recorded. Because numbers were limited, no calculations of significance of these differences have been made, though it is of some interest that, in the college series, Ohio women were significantly shorter than women from the other states, all of which were west of the Mississippi River.

There are a number of known variables in the sample which might influence stature. All of the women whose measurements are recorded in this table were born before the regular use of vitamin D during child-

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[4] Editor's Note: The "bony" measurements, such as the bi-iliac diameter, may be measured with or without a pressure on the calipers adequate to minimize the effect of overlying soft tissues, depending on the investigator's purpose. Moderate pressure was used in this study.

[5] Made in France on specifications supplied by the personnel of the Smithsonian Institution.

TABLE 1

Means and standard deviations of body measurements of adult White women

MEASUREMENT	AGES											
	17–21		30–39	40–49		50–59		60–69		70–79		80–89
	OHIO	MINN.	MINN.	MICH.	MINN.	MICH.	MINN.	MICH.	MINN.	MICH.	MINN.	MINN.
No. of Subjects	160	187	20	12	20	9	20	12	20	10	20	20
Stature, cm	161.4 ±5.9	164.2 ±5.7	165.7 ±4.8	161.1 ±5.2	165.3 ±5.6	158.4 ±4.9	160.6 ±4.3	158.6 ±5.1	162.8 ±4.6	155.1 ±8.1	158.8 ±5.3	155.5 ±6.6
Weight, kg	55.8 ±8.1	57.5 ±7.2	57.8 ±6.0	67.5 ±15.4	62.2 ±11.1	72.5 ±12.1	68.4 ±10.9	72.4 ±7.2	66.2 ±7.7	60.7 ±9.5	57.9 ±9.5	56.7 ±8.3
Chest, Lateral, cm	25.2 ±1.6	25.9 ±1.5	25.5 ±1.6	25.6 ±2.1	25.0 ±1.5	27.6 ±2.4	26.2 ±2.2	26.8 ±1.4	25.8 ±1.9	25.5 ±2.6	24.5 ±1.9	24.5 ±1.8
Chest, Antero-posterior, cm	18.3 ±1.5	18.4 ±1.3	17.5 ±0.9	19.7 ±2.0	18.5 ±1.4	20.5 ±1.8	19.5 ±1.5	21.1 ±1.7	20.4 ±2.4	21.0 ±2.3	20.2 ±1.4	20.0 ±1.8
Arm Girth, Right, cm	26.3 ±2.6	26.7 ±2.4	26.8 ±2.1	30.6 ±4.7	28.8 ±3.4	32.1 ±3.1	30.9 ±2.9	32.2 ±2.4	30.3 ±2.5	30.1 ±4.0	27.7 ±3.0	27.3 ±2.7
Bi-iliac, cm	— —	— —	28.6 ±1.3	29.8 ±2.5	28.6 ±1.8	30.8 ±2.1	30.1 ±1.5	31.1 ±1.9	31.1 ±1.4	31.1 ±1.3	30.6 ±1.6	30.9 ±1.7
Calf Girth Right, cm	35.0 * ±2.4	35.7 * ±2.3	34.6 ±2.2	35.9 ±3.8	35.2 ±3.3	37.0 ±4.1	36.3 ±3.8	37.0 ±3.2	35.0 ±3.2	33.7 ±1.5	32.0 ±3.4	32.9 ±2.9

* Ohio and Minn., calf girth, left.

hood and it is known that the levels of effective sunshine in Ohio and Michigan are lower than in the Western states. Iodine deficiency is a common finding in Michigan and affected about 50% of adolescent girls previous to the iodization of table salt in 1924. Since that time, the use of iodized salt is known to have varied widely.

The adult samples do not measure comparable population segments from the point of view of social stratification although a brief inspection of data available on family income would suggest that the buying power of the two groups was not too different.

Ethnic differences are more difficult to evaluate. Forty per cent of women from Minnesota and 50% from Michigan were native to their respective states. Twenty-seven per cent of Minnesota women were of Scandinavian inheritance and 42% represented the third generation of their families born on American soil. The remaining women were descended from Northern European stock except for 13%, for whom exact data for classification were missing. The Michigan sample also was derived largely from Northern European stock but inheritance was so mixed that further classification seemed unproductive. No one ethnic group dominated the Michigan sample.

Women in the fifth decade appeared to be shorter in both series than the younger subjects and women over 70 years were, on the average, three to four centimeters shorter than in the preceding decade. Numerous studies of college women and the compilation of heights and weights of working women published by Bayer and Gray ('34) would suggest that the stature of women had increased during the past 100 years. The apparent loss of height with age of women between 40 and 50 years, in this series, could be interpreted as reflecting the shorter stature of an earlier period. The lesser height of women over 50 years of age may reflect both an earlier birth date and an actual loss of stature with age.

Twelve women of the Michigan series, ranging in age from 48 to 77 years have been studied repeatedly during the past 10 years. Two of the women one 56 and the other 77 years old showed no change in stature, data on height was lacking for one subject in the seventies, and the other 9 subjects appeared to have lost from 0.5 to 2.0 centimeters in height. Losses of stature increased with the period of observation. There were both losses and gains of weight in individual women. Elderton *et al.* ('28) and Reynolds and Asakawa ('50) reported a similar trend for stature of women to decrease with age.

One study published in 1931 of 26 women born in Holland, Michigan, of Dutch stock was found in the literature (Steggerda). The women were characterized as "middle aged" and were slightly taller and deeper chested than the present sample. The most significant difference in the comparable measurements was in the girth of the upper arm which was 4 to 5 cm smaller in the woman of Dutch ancestry.

The measurements of Negro women are given in table 2. The differences in measurements of Negro and White subjects from Michigan were slight and, for the most part, inconsistent. In general, the transverse chest, bi-iliac and bi-trochanter widths and calf girth measurements were smaller in the Negro women. More of the Negro women reported employment requiring physical work than White women. Tasks such as ironing, cleaning walls and floors were done regularly and the differences in measurement are in keeping with the clinical impression that the Negro women of the series were more muscular and less fat than White women of the same height and weight. Wolff and Steggerda ('43) reported similar measurements of 100 Negro women of college age living in the South. The older women, most of whom had migrated from the South as adults, were shorter, heavier and larger in each of the width and girth measurements than the college series. Both groups of subjects were of the mixed blood characteristic of the American Negro. The number of subjects in the 7th and 8th decade was too small to study changes in stature with age in the Negro women of this series. Michelson ('43) found no difference in height of young adult Negro women measured in 1923 and 1941.

TABLE 2

Body measurements of adult Negro women

MEASUREMENT	AGES, YEARS 50–59	60–69
No. of Subjects	23	21
Stature, cm	161.0 ± 7.5	155.4 ± 7.7
Weight, kg	73.8 ± 15.7	69.9 ± 13.1
Chest, Lateral, cm	28.1 ± 2.9	27.6 ± 2.2
Chest, Antero-Posterior, cm	20.3 ± 1.9	20.5 ± 1.9
Arm Girth, Rt., cm	31.7 ± 4.0	32.4 ± 3.7
Bi-iliac, cm	29.9 ± 3.1	30.0 ± 2.2
Bi-trochanteric, cm	32.2 ± 3.1	32.2 ± 2.3
Calf Girth, Rt., cm	35.7 ± 3.7	36.2 ± 3.3

Maximum grip of the right and left hands[6] of this series of subjects is reported in table 3. The grip of the Negro subjects is higher for both hands at each age group, which again confirms the impression of better muscular development than that found in the White women.

Anthropometric measurements were made on this series of women to increase the usefulness of the total data in interpreting nutritional status. The measurements alone are merely descriptive of a population. A few low values of hemoglobin and vitamin C were found in studies of the blood chemistry (Chaloupka, Leverton and Diedricksen, '51, Roderuck *et al.*, '55, and Swanson, Leverton, Gram, Roberts and Pesik, '52) but clinical examinations did not reveal symptoms related to deficiency of nutrients. The food eaten was such that nutrient intakes correlated closely with intakes of calories and protein (Ohlson *et al.*, '52). The lower caloric intakes tended to be generally poor in all nutrients rather than specifically deficient in one. In spite of a large number of cases consuming fewer than 1800 calories per day, weight in excess of standards was frequent in the Michigan sample even when an allowance was made for greater size of chest and hips. Serious underweight was not found. Therefore the relation of excess weight to the measurements chosen was studied in a separate series of cases selected as a part of another project on weight control.

Table 4 presents the data on women of widely varying weight but chosen so that each group of three subjects was matched for age, height and other physiological characteristics. Each measurement increases with increased weight and the increases are larger between frankly obese subjects and those of normal weight for height than between the women of normal weight and those underweight. Skinfold measurements of the abdomen, back, upper arm and thigh just above the knee made with a skinfold caliper using the directions as outlined by the Laboratory of Physiological Hygiene of the University of Minnesota were plotted against percent deviation of weight in figure 1. Apparently the measurements given in table 4 do measure differences in fatness as well as possible differences in body build of the three groups of subject.

The relations between weight and the measurements chosen were explored further in figure 2 which records the change in each measurement which occurred in a group of obese subjects with increasing amount of weight lost. Each subject was reduced in weight with a diet

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[6] Measured with a Narragansett dynamometer.

TABLE 3

Hand grip in kg of adult White and Negro women

AGE IN YEARS	MICHIGAN NEGRO			MICHIGAN WHITE			MINNESOTA WHITE		
	No.	Right Hand	Left Hand	No.	Right Hand	Left Hand	No.	Right Hand	Left Hand
30–39							20	30.6 ± 4.1	26.3 ± 3.3
40–49				12	30.1 ± 5.2	27.7 ± 6.0	20	28.2 ± 3.2	25.0 ± 3.6
50–59	23	32.3 ± 7.6	31.1 ± 6.3	9	28.4 ± 6.1	27.2 ± 6.7	20	27.0 ± 2.7	24.4 ± 4.0
60–69	21	28.8 ± 8.3	28.2 ± 7.1	12	23.8 ± 4.6	22.7 ± 5.2	20	24.7 ± 3.6	22.6 ± 4.0
70–79	3	23.3 ± 2.9	21.7 ± 2.9	10	20.7 ± 3.5	22.1 ± 5.5	20	20.5 ± 4.3	17.4 ± 3.4
80–89	3	21.0 ± 3.6	20.0 ± 5.0	1	17	15	20	16.6 ± 3.2	15.3 ± 3.6

TABLE 4

Body measurements of selected groups of underweight, average-weight and overweight women

GROUP	NO.	RANGE OF AGE	HEIGHT	RANGE OF WEIGHT	CHEST, LATERAL	CHEST, ANTERO-POSTERIOR	ARM GIRTH, RT.	BI-ILIAC	BI-TRO-CHANTERIC	CALF GIRTH, RT.
			cm	kg	cm	cm	cm	cm	cm	cm
Under-weight	7	25 to 51	163.4	45.0 to 54.8	23.9	16.6	23.5	26.7	30.8	32.3
Average-weight	7	25 to 52	164.8	53.5 to 69.9	25.4	17.9	27.6	28.3	31.8	35.9
Over-weight	7	25 to 57	164.5	76.2 to 112.0	27.2	22.5	33.4	33.0	36.4	40.0

containing 85 to 90 grams of protein per day and food to provide a total deficit of about 800 calories per subject per day. The ratios of fat to carbohydrate used varied widely but because of the caloric limitation, most of the protein was obtained from foods of animal origin. The mean of each measurement is reduced with weight reduction but the most rapid change is seen in the girth of the upper arm.[7] The apparent increases in size of the antero-posterior chest, the bi-iliac and bi-trochanter widths in some subjects who lost a minimum amount of weight is of some interest and may reflect the quality of the diet previous to reduction which was known to be low in protein and certain nutrients associated with protein in food.[8] Biskind ('44) observed that there was a decrease in the size of certain of the fat pads particularly over the hips without much change of weight in subjects given a therapeutic dose

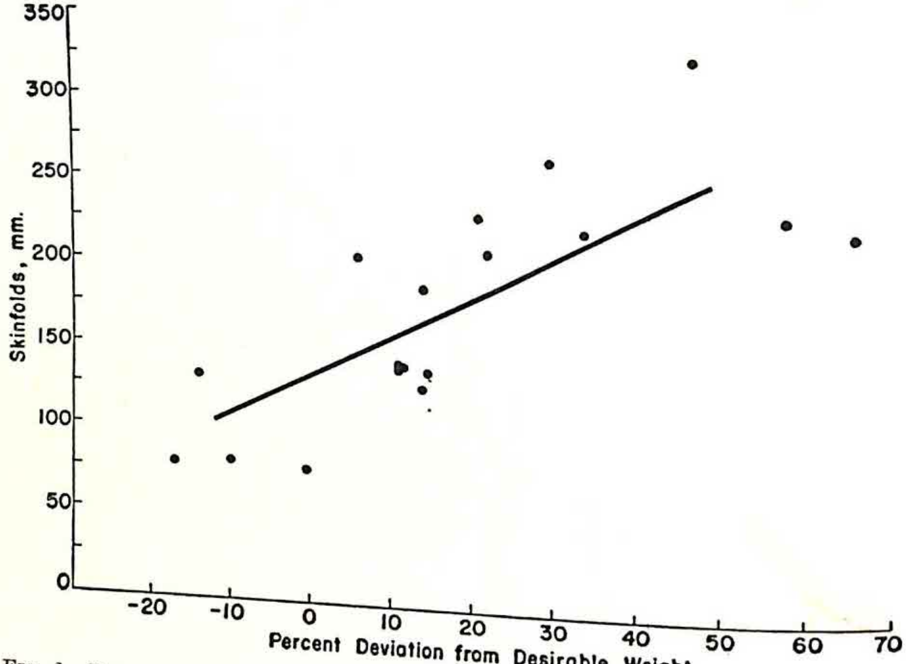

FIG. 1. RELATION OF THE SUM OF SKINFOLD MEASUREMENTS TO THE ESTIMATED DEVIATION FROM DESIRED WEIGHT OF 18 SUBJECTS.

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[7] *Cf.* J. Brožek, 1953, Thigh girth and nutritional status. Human Biol., *25*: 159-162.

[8] Editor's Note: Some apparent increments may reflect the variability present in all repeated measurements.

of a vitamin B mixture. Patients with a history of a poor diet consisting largely of refined carbohydrate have been observed who, when transferred to a diet high in animal protein and adequate in all known nutrients, have shown a prolonged retention of nitrogen during weight loss and marked figure changes not entirely explained by the reduction of fat pads (Ohlson *et al.*, '55). A spontaneous increase in activity followed weight reduction in these cases suggesting a previous malnutrition in spite of overweight.

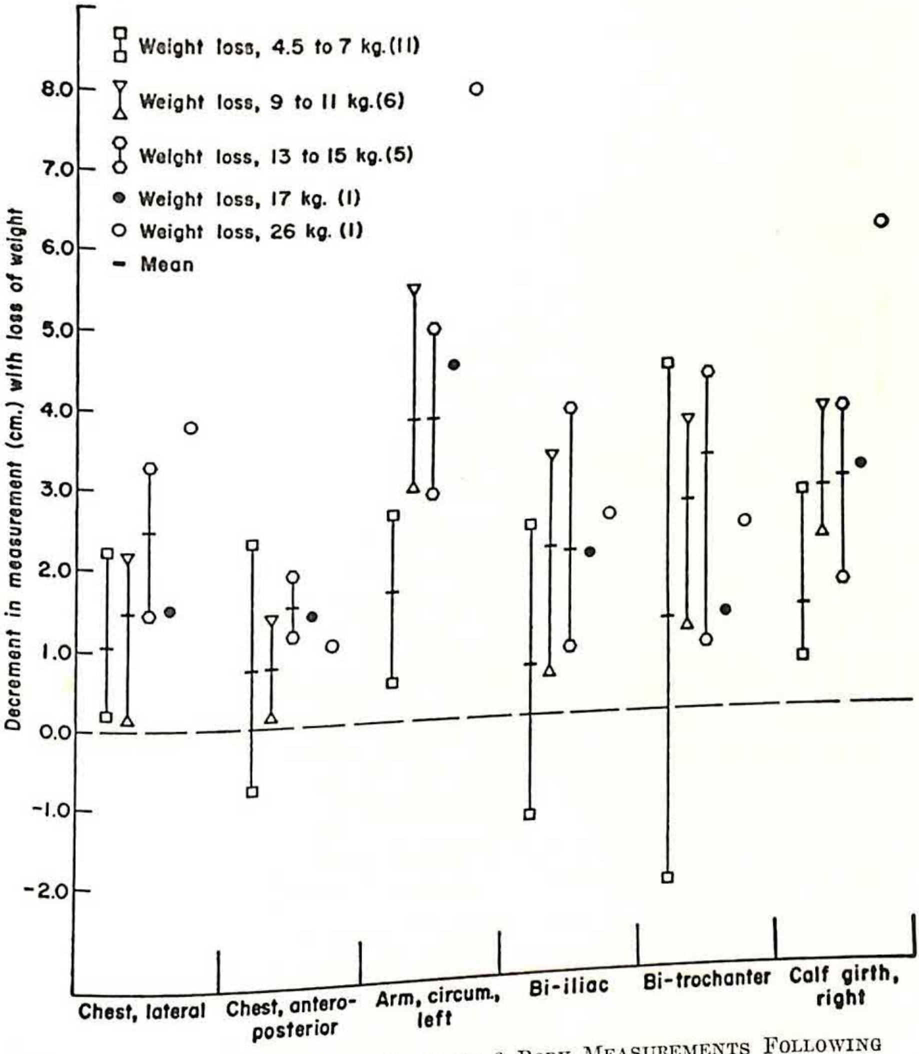

FIG. 2. RANGE OF CHANGE IN EACH OF 6 BODY MEASUREMENTS FOLLOWING WEIGHT LOSSES OF FROM 4.5 TO 26 KG.

DISCUSSION

There are only a few comments which can be made on the data presented. The White women of the two communities studied were quite different in physical build and the Michigan sample appeared to be considerably larger both in skeletal measurements of breadth and in fatness. Except for height and weight, there are almost no physical measurements of women of adult age groups which may be compared with this series. Women from both states in the age period 30 to 59 were somewhat taller and heavier than reported by Bayer and Gray in 1934 for working women in England and a number of areas of the United States. The sample of Minnesota White women compared rather closely in girth of upper arm and calf with the Bayer and Gray sample, particularly in the 30 and 60 year age group, but women from Michigan were consistently larger. Both Minnesota and Michigan women tended to have smaller chest measurement except for the 50 to 59 age group.

Most of the reports cited above were published before 1931 and since there was a trend toward a steady increase in height and weight in the various series from 1912 to 1931, it is probable that this study measures, in part at least, the apparent trend toward greater stature in the population as a whole. Height and weight as reported in this study also are greater in both samples and at all ages than heights and weights reported by O'Brien and Shelton in 1941 in their study of measurements of 10,042 women for purposes of pattern construction. Only about 5% of the latter sample were selected from the North Central area and 4 of the 8 areas sampled were from the Southeast. Data reported by states would suggest that important state differences may exist. Techniques for measuring height were such that the O'Brien and Shelton series might result in slightly lower values for height than would be obtained by the procedures reported in this paper.

Other than those previously quoted, the only other extensive published study of measurements of adult women is that of Randall and Munro ('49) on Army women from the ages of 18 to 39. Unfortunately data are included in the report only through age 30, and this study, like that of O'Brien and Shelton was done for purposes of pattern construction, and except for height and weight, the measurements taken do not compare directly with those used in these observations. A limited number of measurements of subjects in the adult age brackets have been recorded on special groups. Angel ('49) measured the height, weight, transverse and antero-posterior chest, and bi-iliac and bi-trochanter width of a series of obese women, and Trotter and Gleser ('51) made similar measurements on cadavers of the Terry Collection. In so far as comparable age data could be separated, the figures reported here are within the ranges recorded by these investigators.

This paper has been presented as an interval report, since the work, particularly with the Michigan series, is being continued with plans for serial measurements of the original sample. It is apparent that it is not possible to generalize from the samples studied to other population segments even with the same communities. However, the measurements made appear to have some merit in determining both build and fatness. The addition of selected skin fold measurements further defines fatness as related to body build.

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OBESITY AND DISEASE

BY ARNOLD B. KURLANDER, SIDNEY ABRAHAM AND
J. WALLACE RION

Division of Special Health Services, Public Health Service,
U. S. Department of Health, Education, and Welfare

IN recent years weight reduction programs have been widely advocated as a preventive measure against heart disease and diabetes. The basis for these programs lies partly in life insurance studies. Overweight persons, limited to substandard life insurance because of excess weight, were found to have a higher mortality than persons accepted for standard insurance (Armstrong *et al.*, '51). Men markedly overweight had a mortality of 79% above the standard risk group as compared with 42% for those who were moderately overweight, and among women the increased mortality in excess of the standard risk group was 61% for markedly overweight and 42% for moderately overweight. The study also indicated that the excess mortality is due largely to a higher death rate from the degenerative diseases, particularly from cardiovascular diseases and from diabetes. Deaths due to diabetes, for example, showed more than three times the expected diabetes mortality.

In addition to insurance studies, other data are available which show that the prevalence of conditions such as hyperglycemia and high blood pressure increase with the degree of excess weight. The findings of Joslin and his associates ('52) indicated a marked influence of overweight on the development of diabetes. A review of 3,000 clinical records isclosed that 62.7% of males and 67.4% of females showed evidence of verweight at onset of disease. With regard to high blood pressure, Master, Dublin, and Marks ('50) surveyed 74,000 industrial workers and found that at every age and in both sexes there was an increase in average blood pressure with increase of body weight for a given height.

It is worth noting that these studies of the relationship of obesity to health and disease all measure "obesity" in terms of departure of actual weight from a height-weight standard. Such measurements do not differentiate between the effects of the fat, fluid, bone, and muscle components of the body upon weight status of persons of a given height. The departure from a height-weight standard may in some instances be due to body components other than body fat. This possibility is suggested in reports by a number of investigators. A study by Welham and Behnke ('42) concluded that, "according to standard height-weight tables, the majority of the football players could be classified as unfit for military service, and as not qualified for first class insurance by reason of overweight." Actually, overweight in these men was due largely to body components other than body fat. A necropsy study by Spain and others ('53) with special reference to somatotypes (body build classifications according to Sheldon *et al.*, '40) showed that of 38 persons whose deaths were due to coronary heart disease, 24 were classified as dominant mesomorphs (tendency toward muscularity). Gertler and his associates ('51) in clinical studies on young adults with coronary heart disease also found more dominant mesomorphs than endomorphs. Robinson and Brucer ('40) studied the relationship of obesity and body build to hypertension and concluded that whereas body build is an important predisposing factor, obesity as such was a small factor.*

Morbidity, as well as additional mortality, investigations, are needed to clarify the significance of departures from "normal" body weight. A Multiple Screening Project conducted at D. C. General Hospital in Washington, D. C. from January 23, 1952, to October 24, 1952, afforded an opportunity to study the relationship of various weight evaluation methods to the presence or absence of disease. Other aspects of this multiple screening project have already been reported (Kurlander *et al.*, '54, '55). Four methods of measuring fat were used, varying in the manner in which they included body components other than body fat. The criteria were:

1. Gross body weight,
2. Standard Height-Weight,
3. Pryor Width-Weight,
4. Skinfold thickness.

Each of the methods shows a different degree of crudeness, as far as obesity is concerned, since other components of total body weight enter in varying degrees. The standard height-weight is the earliest and still the most commonly used method for measuring "obesity." The widely used tables of standard weights for age, sex, and height resulted from the Medico-Actuarial Mortality Investigation (Association of Life Insurance Medical Directors and the Actuarial Society of America, '12) of policy holders accepted for insurance in the United States and Canada between 1885 and 1909.

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* Editor's Note: For a discussion of "Obesity and heart disease" see A. Keys, 1955, J. Chron. Dis., *1*: 456-461.

The Pryor ('40) width-weight standards call for an objective measure of the contribution of the body structure to total body weight and take into consideration the width of the hips and chest as well as the height of the subject. Thus this method better measures obesity since it considers lateral development in addition to height. The standard weights shown in the published Pryor width-weight tables were predicted from a multiple-regression equation in terms of height, bi-iliac diameter and the lateral thoracic diameter for a given age and sex.

In the D. C. General Hospital Multiple Screening Project a wooden caliper with a sliding metal arm was used to record the width of the chest and hips. The width of the chest was measured at approximately the nipple level. In taking the measurement, the arms of the caliper were pressed together until they touched the body on both sides without pressure.* The instructions for the measurement of the hips were to measure with firm pressure the greatest width at the crest of the ilium. Subjects were required only to remove their outer garments.

The skinfold thickness technique used was essentially as recommended by Brožek and Keys ('51). Measurements of the thickness of the skinfold were made at three sites: midway on the posterior line of the upper arm, above the iliac crest (in the midaxillary line), and below the left scapula. These sites were selected since they did not require that the screenees disrobe and were suggested as appropriate for surveys by Keys and Brožek ('53).

The skinfolds were measured by a caliper furnished by Dr. Keys of the University of Minnesota in 1952. The area of the contact points of this caliper was 20 square mm and the opening pressure was 530 gms. An index of body fat was obtained by averaging the three skinfold thickness values.

In the D. C. General Hospital Multiple Screening Project, screening tests and physical examinations were given to persons who applied to the admitting and emergency office for hospital or outpatient care. A total of 964 persons were examined of whom 827 or 86% were Negro. In order to simplify interpretation of the data and because so few whites were included, only the results on Negroes were used in this obesity study.

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* Editor's Note: The thoracic diameter, when measured without pressure, includes also the subcutaneous adipose tissue.

The obesity classifications were related to the results of diagnostic investigations. Diagnostic criteria for heart disease and hypertension have been described in detail in previous papers (Kurlander *et al.*, '55). For each of the four obesity measures, "obese" persons were somewhat arbitrarily defined as those falling in the upper fifth of an array of the measurements obtained. For the Standard Height-Weight and the Pryor Width-Weight estimation procedures, percentage deviations from the standard shown in the tables were used. These percentage deviations were arrayed from largest to smallest and the upper 20% of the distribution considered as overweight. While this is not an entirely satisfactory definition of overweight, it was the only procedure that could be uniformly applied since there were no adequate standards for total body weight or skinfold thickness.

WEIGHT MEASURES AND CARDIOVASCULAR DISEASE

The sample consists of 643 persons with all four measures of obesity and a complete diagnostic work-up for cardiovascular disease. As judged by the standard height-weight tables, the 198 males in this group tended to be somewhat underweight, with 129 below the standard and only 69 at or above their standard weight. On the other hand the 445 females appeared, as a group, to be overweight with only 184 below standard weight and 261 at or above.

In order to study the relationship of obesity to disease, rheumatic heart disease, syphilitic heart disease and peripheral vascular diseases were included in the negative group since in general there appears to be little justification for relating these conditions with obesity. In considering relationship to heart disease, persons with hypertension alone were included in the non-heart disease or negative group.

The results of applying the four methods for determining obesity status to the 198 males (46 with heart disease, 20 with hypertension) are shown in Appendix I, while the values obtained for 445 females (93 with heart disease, 52 with hypertension) are shown in Appendix II.

Table 1 contains the crude and age-adjusted rates of heart disease observed in obese and normal or thin males when four different methods of designating the obese segment of the population are used. Age adjustment of these rates was desirable, since some of the difference in the prevalence of disease observed in the two groups was due to a greater average age in the obese group and since heart disease is more prevalent in the older age groups. This tended to magnify differences in prevalence. Due to the small number of cases involved, data for hypertension among males are not shown.

It will be noted that actual weight, which of course includes all body components, differentiates those persons with heart disease from those persons without heart disease about as well as the other two methods of designating overweight. After adjustment for age differences, the 20% of the males most overweight had a prevalence of heart disease over twice as great as the remaining 80%. *On the other hand, the skinfold thickness measurement which primarily measures body fat showed no direct relationship to the prevalence of heart disease.* These data seem to support a hypothesis that among males it is body components other than body fat that are associated with the excess heart disease mortality among overweight observed in life insurance studies when overweight was defined by the height-weight method.

TABLE 1

Crude and age adjusted rates of heart disease in Negro male patients identified as obese by four different methods of obesity classification

METHOD	OBESE (N = 40)[1] Percent with Heart Disease Crude Rate	Age Adjusted Rate	NORMAL OR THIN (N = 158) Percent with Heart Disease Crude Rate	Age Adjusted Rate
Actual weight	45.0	38.7	17.7	18.4
Standard height-weight	45.0	40.0	17.7	18.3
Pryor width-weight	42.5	38.5	18.4	18.5
Skinfold thickness	25.0	22.1	22.8	23.6

[1] Upper " fifth " of participants were designated obese.

The data presented in table 1 provide no evidence as to relationship between obesity and heart disease. It is quite likely that some persons with disease are thin because weight reduction is part of the treatment for the disease or maybe the effect of the disease itself. It would have been desirable to have applied the obesity measures before heart disease or hypertension developed to the point where it might have affected weight status—or even better, before the disease occurred. Some information can be gained by studying separately those males who were previously unaware of their heart disease and whose illness was previously unknown to the Outpatient Department of the D. C. General Hospital. In these patients presumably the heart disease had less opportunity to affect the individual's weight status. There were 22 previously unknown cases out of the total of 46 shown in table 1. The results are shown in table 2. While the numbers involved are small, the results are similar to those given in table 1 and suggest that body fat may not be important in contributing to the presence of heart disease.

TABLE 2

Previously unknown heart disease in Negro males

METHOD	OBESE (N = 40)	NORMAL OR THIN (N = 158)
	Percent with previously unknown heart disease	Percent with previously unknown heart disease
Actual weight	17.5	9.5
Standard height-weight	20.0	8.9
Pryor width-weight	15.0	10.1
Skinfold thickness	10.0	11.4

Tables 3 and 4 contain the crude and age adjusted rates of heart disease and hypertension observed in 445 Negro females classed as obese and normal or "thin." Here the age distributions of the two groups were quite similar so that the age adjustment of the percentages has little effect. For heart disease, the differences were small and the prevalence was not consistently higher in the overweight groups. On the other hand, the prevalence of hypertension in the overweight group was nearly twice as high in comparison to the normal or underweight group. This relationship was about the same, regardless of the obesity measure used. Of the 93 cases of heart disease among the females, 28 were previously unknown. When these are considered separately, as shown in table 5, prevalence is somewhat higher in the overweight as compared to the normal or underweight groups. These differences were about the same, however, regardless of the obesity measure used.

TABLE 3

Heart disease in Negro females

METHOD	OBESE (N = 89) Percent with heart disease		NORMAL OR THIN (N = 356) Percent with heart disease	
	crude rate	Age adjusted rate	crude rate	Age adjusted rate
Actual weight	24.7	24.4	19.9	19.8
Standard height-weight	21.3	22.3	20.8	20.3
Pryor width-weight	19.1	19.7	21.3	21.1
Skinfold thickness	27.0	25.0	19.4	20.0

TABLE 4

Hypertension in Nego females

METHOD	OBESE (N = 89) Percent with hypertension		NORMAL OR THIN (N = 356) Percent with hypertension	
	crude rate	Age adjusted rate	crude rate	Age adjusted rate
Actual weight	18.0	17.6	10.1	10.1
Standard height-weight	18.0	18.3	10.1	11.6
Pryor width-weight	18.0	18.3	10.1	10.1
Skinfold thickness	18.0	16.9	10.1	10.3

TABLE 5

Previously unknown heart disease in Negro females

METHOD	OBESE (N = 89) Percent with previously unknown heart disease	NORMAL OR THIN (N = 356) Percent with previously unknown heart disease
Actual weight	9.0	5.6
Standard height-weight	7.9	5.9
Pryor width-weight	7.9	5.9
Skinfold thickness	9.0	5.6

CONCLUSIONS

Data obtained from the D. C. General Hospital Multiple Screening Project throw some doubt on the role of body fat in contributing critically to the development of heart disease among males. While the numbers involved were not large and were confined to a Negro population, the results were consistent with the hypothesis that body components other than body fat are associated with excess mortality from cardiovascular disease observed in life insurance studies of overweight men. However, among females no such evidence was obtained.

The methodology used in this study is fairly simple and easily applied. The findings should be verified by similar studies in other population groups. Moreover, it seems important that more longitudinal studies dealing with the relationship of obesity to the development of disease be instituted.

1. Much of our knowledge regarding the role of obesity in the etiology of disease stems from studies in which "obesity" was defined as departure of body weight from a height-weight standard.

2. A number of studies suggest that some (or all) of the association between weight and disease may actually be due to body build rather than to obesity.

3. A study is reported here in which obesity was defined by four criteria, ranging from measures which tended to include all body components(*e.g.*, body fat, bone, muscle) to those which tended to include only body fat. The prevalence of heart disease and hypertension was compared in obese and normal or "thin" persons.

4. For males, when measures of obesity which tended to include only body fat (*i.e.*, skinfold thickness) were used, there was no relationship observed between heart disease and obesity. When measures of obesity which included other body components were used there was a pronounced relationship between heart disease and obesity.

5. In females about the same relationship between heart disease and obesity and between hypertension and obesity was observed regardless of the measure of obesity used.

6. It is concluded that the results obtained for males behaved in a fashion consistent with the hypothesis that it is body components other than body fat that are associated with the excess mortality as observed in life insurance studies of overweight men. For females, however, no

evidence was obtained which suggested that body components other than body fat have been responsible for the increased morbidity and mortality observed in the overweights as defined by the standard height-weight tables.

7. It is suggested that the methodology used here be applied in other studies and that these findings be verified. Considerable emphasis should be placed upon longitudinal studies of the relationship between body fat and the development of disease.

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APPENDIX I

Negro males. Total group and those with diagnosed heart disease or hypertension

HEART DISEASE											
Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	198	46	Total	198	46	Total	198	46	Total	198	46
240 & over	6	3	160–169	4	2	130–139	3	1	60–64	–	–
230–239	1	1	150–159	2	1	120–129	6	4	55–59	–	–
220–229	1	0	140–149	0	0	110–119	9	4	50–54	–	–
210–219	5	2	130–139	3	2	100–109	29	9	45–49	–	–
200–209	7	4	120–129	14	6	90– 99	72	14	40–44	–	–
190–199	5	2	110–119	15	7	80– 89	65	12	35–39	3	2
180–189	11	5	100–109	31	4	70– 79	12	2	30–34	2	2
170–179	13	2	90– 99	65	15	60– 69	2	0	25–29	4	0
160–169	19	5	80– 89	45	6	50– 59	0	0	20–24	8	2
150–159	21	4	70– 79	15	3				15–19	22	4
140–149	37	6	60– 69	4	0				10–14	44	14
130–139	35	5							5– 9	104	22
120–129	19	4							Less than 5	11	0
110–119	13	3									
100–109	3	0									
90– 99	2	0									

* Shown as a percentage of the standard.

HYPERTENSION

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	198	20	Total	198	20	Total	198	20	Total	198	20
240 & over	6	2	160–169	4	1	130–139	3	0	60–64	–	–
230–239	1	0	150–159	2	1	120–129	6	1	55–59	–	–
220–229	1	0	140–149	0	0	110–119	9	1	50–54	–	–
210–219	5	0	130–139	3	0	100–109	29	2	45–49	–	–
200–209	7	0	120–129	14	0	90– 99	72	7	40–44	–	–
190–199	5	0	110–119	15	2	80– 89	65	8	35–39	3	0
180–189	11	2	100–109	31	3	70– 79	12	1	30–34	2	0
170–179	13	0	90– 99	65	5	60– 69	2	0	25–29	4	0
160–169	19	5	80– 89	45	6	50– 59	0	0	20–24	8	0
150–159	21	1	70– 79	15	2				15–19	22	3
140–149	37	2	60– 69	4	0				10–14	44	6
130–139	35	5							5– 9	104	10
120–129	19	2							Less than 5	11	1
110–119	13	1									
100–109	3	0									
90– 99	2	0									

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* Shown as a percentage of the standard.

APPENDIX II

Negro females. Total group and those with diagnosed heart disease or hypertension

HEART DISEASE

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	445	93	Total	445	93	Total	445	93	Total	445	93
250 & over	15	6	200 & over	5	2	170 & over	1	–	60–64	1	1
240–249	5	1	190–199	2	0	160–169	1	–	55–59	1	0
230–239	9	1	180–189	6	2	150–159	3	1	50–54	7	2
220–229	7	2	170–179	9	3	140–149	13	5	45–49	3	0
210–219	8	2	160–169	10	3	130–139	12	2	40–44	20	9
200–209	20	6	150–159	16	2	120–129	29	7	35–39	25	5
190–199	13	3	140–149	23	5	110–119	42	4	30–34	34	8
180–189	20	1	130–139	28	3	100–109	102	26	25–29	38	7
170–179	37	14	120–129	40	10	90– 99	127	29	20–24	61	15
160–169	43	9	110–119	46	16	80– 89	77	13	15–19	68	17
150–159	33	8	100–109	76	13	70– 79	35	6	10–14	78	16
140–149	39	10	90– 99	75	19	60– 69	3	–	5– 9	102	12
130–139	49	11	80– 89	58	7				Less than 5	7	1
120–129	49	6	70– 79	39	4						
110–119	47	7	60– 69	11	4						
100–109	27	1	50– 59	1	–						
90– 99	15	4									
Less than 90	9	1									

* Shown as a percentage of the standard.

HYPERTENSION

Actual Weight			Standard Height-Weight			Pryor Width-Weight			Skinfold		
Weight (Pounds)	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Relative Body Weight*	Number Tested	Number Diagnosed	Average Skinfold (mm)	Number Tested	Number Diagnosed
Total	445	52	Total	445	52	Total	445	52	Total	445	52
250 & over	15	1	200 & over	5	0	170 & over	1	0	60–64	1	0
240–249	5	1				160–169	1	0	55–59	1	0
230–239	9	4	190–199	2	1	150–159	3	0	50–54	7	1
220–229	7	2	180–189	6	0	140–149	13	3	45–49	3	1
210–219	8	1	170–179	9	2	130–139	12	4	40–44	20	5
200–209	20	5	160–169	10	4	120–129	29	5	35–39	25	5
190–199	13	1	150–159	16	4	110–119	42	5	30–34	34	4
180–189	20	2	140–149	23	3	100–109	102	11	25–29	38	8
170–179	37	6	130–139	28	5	90– 99	127	18	20–24	61	6
160–169	43	2	120–129	40	5	80– 89	77	5	15–19	68	6
150–159	33	6	110–119	46	4	70– 79	35	0	10–14	78	9
140–149	39	4	100–109	76	8	60– 69	3	1	5– 9	102	6
130–139	49	6	90– 99	75	5				Less than 5	7	1
120–129	49	5	80– 89	58	7						
110–119	47	4	70– 79	39	3						
100–109	27	1	60– 69	11	0						
90– 99	15	0	50– 59	1	1						
Less than 90	9	1									

* Shown as a percentage of the standard.

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BODY WEIGHT: FACTS FROM LIFE INSURANCE RECORDS

BY HERBERT H. MARKS
Metropolitan Life Insurance Company

THE simplest objective facts on applicants for insurance that are easily and routinely obtained and are of the utmost value are their height and weight. Measurements of chest and abdominal girths have been available and used, and, as will be noted later, measurements of spine length were collected by one company. But their usefulness has been entirely secondary to the more voluminous and valuable data on heights and weights. The latter items of measurement permit ready classification of applicants for purposes of mortality investigations. The resulting body of information on the relationship of body weight to longevity has been of great significance to medicine and public health. Particularly is this true with regard to overweight, which is recognized as one of the principal impairments among persons applying for insurance and is associated with the early onset of degenerative diseases, particularly arteriosclerotic conditions affecting the heart and circulatory system.

It is hard for us to appreciate that a century or more ago, when life insurance began its long period of expansion, the well nourished stout man was looked on with favor as the best risk for life insurance. In those days the wasting diseases like tuberculosis and other acute infectious diseases were chiefly responsible for the very high death rates that prevailed in the population. In the absence of any sound medico-actuarial studies, the facts on the long-term outlook were unknown. How much this situation has changed will be developed in the course of these remarks.

DEVELOPMENT OF HEIGHT-WEIGHT TABLES FROM LIFE INSURANCE RECORDS

Actually, figures on the relationship between body weight and other body measurements go back scarcely a century. The earliest insurance compilations of data on body weight were based upon small numbers of cases and obviously could give no accurate picture of the variations by height and age (*Medico-Actuarial Mortality Investigation*, vol. 1, '12, p. 11; Dingman, '46).

The first table based upon a considerable volume of statistics which took account of age was prepared by the Association of Life Insurance Medical Directors in 1897 (cited in Shepherd, '12). It was based upon 74,162 male applicants accepted for life insurance in the United States and Canada. In 1900 the National Fraternal Congress published a similar table of heights and weights according to age based upon approximately 135,000 insured in fraternal orders in the United States and Canada (cited in *Medico-Actuarial Mortality Investigation*, vol. 1, '12, pp. 11 and 19). Shortly thereafter, similar tables were prepared by a number of European insurance companies (*ibid.*, pp. 11 and 20).

The first extensive tables for women were those brought out by Dr. Faneuil S. Weisse ('12) of the Mutual Life Insurance Company of New York, in 1908. These tables were based upon height and weights of about 60,000 cases insured over the previous decade. The records for 25,000 of these women were obtained from the Mutual Life and the balance of 35,000 were supplied by the New York Life Insurance Company.

On the basis of these various sources, insurance companies prepared tables for their guidance in selection of applicants. In the first large intercompany investigation of various classes of risks in this country, known as the *Specialized Mortality Investigation* and published in 1903, appeared a table of weights covering a broad range of "normals" which was derived from these earlier studies, and, in addition, three other weight groups were defined, one for underweights and two for overweights of varying degree.

The tables of average weight for height which have been in vogue for over 40 years in this country as well as in many others were derived from the next intercompany study known as the *Medico-Actuarial Mortality Investigation* ('12-'14). This was a broad study covering the relationship of build to mortality and of the mortality associated with a selected list of impairments and occupations among persons accepted as standard risks. The results of this study appeared in a series of volumes issued between 1912 and 1914. A goodly part of the first volume is devoted to the detailed facts on heights and weights of the insured persons. The data on men were derived from samples of the records of standard lives during 1885 to 1900 inclusive. The number of such cases totaled 221,819. The data on women were obtained partly in the same way, but since this method provided facts on only 10,000 cases, four companies provided supplementary data on women insured after 1900. The great bulk of these supplementary data were furnished by one company. In fact, of the total of the approximately 135,000 policies on the lives of women, approximately two-thirds were from that company. Heights and weights were taken in ordinary indoor clothing, with shoes on. From this material graduated tables of heights and weights were prepared for men and for women, and these have been in wide use ever since.

Subsequently, about 25 years ago, in connection with the *Medical Impairment Study, 1929* ('31), another large-scale intercompany investigation, height-weight data were again collected. The companies were requested to furnish these data on 2% of the standard cases, except at ages under 20 where data were obtained for all individuals. This yielded 667,000 cases on males and 85,000 on females. Except at ages under 25, the differences between the average weights in the old and new tables were remarkably small—so small in fact, that it was decided not to revise the standard height-weight tables except for ages under 25.

It is interesting to observe that the average heights of both men and women in the 1929 study were not significantly different from those observed in the *Medico-Actuarial Mortality Investigation* a generation earlier. The relative stability of both average heights and weights is rather significant because the level of the population to which this type of insurance was sold had gradually changed, and moreover there were significant changes in the ethnic composition of the population. In 1900, $1,000, the minimum for standard Ordinary policies, was a relatively large amount of money, so that most of the insurance of this type was issued on persons in the middle and wealthier classes. With the gradual change in the price level and the increase in wage levels, a steadily increasing number of persons in the clerical and skilled worker group purchased insurance of this kind so that they accounted for a distinctly larger proportion of persons carrying Ordinary insurance during the period covered by the *Medical Impairment Study, 1929*. At the same time, in the period from 1880 on, the number of immigrants rose rapidly. Between 1900 and 1914, the period of heaviest immigration, a large proportion of the immigrants were from Southern and Eastern Europe. They were generally of shorter stature and of slighter build than the earlier immigrants or the second and third generation descendants of these earlier immigrants. This is probably one of the chief reasons why the trends in build derived from life insurance records are not in agreement with those principally based upon college entrants that indicated significant increase both in stature and weight between successive generations over the same period of time.

BUILD AND MORTALITY

For this Conference, the facts of major interest are those relating to the variations in mortality, both in the aggregate and by cause, that are associated with differences in relative weight. The facts on mortality pertain generally to classifications according to either absolute or percentage deviations from average weight for height and age. The findings in broad height groups and in cases with waist girth in excess of chest girth were also ascertained. There have been two comprehensive intercompany investigations along these lines under the joint auspices of medical directors and actuaries, namely, the 1912 *Medico-Actuarial Mortality Investigation* and the *Medical Impairment Study, 1929*.[1] There is, however, useful information also in the earlier (1903) *Specialized Mortality Investigation*. In addition, there have been a large number of separate studies based upon the experience of individual companies.

Certain basic facts relating to the nature of these studies deserve emphasis.[2] (1) They are essentially long range follow-up studies based upon a considerable number of lives. (2) The initial selection of cases and the subsequent evaluation are entirely independent and the evaluation is entirely objective. (3) These studies relate to presumably healthy persons, selected after medical examination, who are in better than average circumstances, free of serious defects, and in safe occupations. They do not relate to a cross section of the general population. Insofar as certain of the more serious impairments causing rating or rejection for life insurance are more frequent in overweights than in persons of less weight, the results understate, relatively, the mortality associated with overweight.

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[1] Another investigation of this kind has already been planned and is under way.

[2] A fuller statement on the nature, the advantages and limitations of these studies will be found in a paper by Lew ('54).

The results of these investigations are presented in the form of mortality ratios which show the percentage of actual to expected deaths. This percentage relates the number of deaths that occurred among persons in a specific category to the number that would have occurred if their death rates had been the same as those experienced by age and duration among persons upon whom the mortality standard is based. Except as noted, this mortality standard relates to persons insured under standard Ordinary policies during the same period. In the more recent studies, mortality ratios were computed for each of the major causes of death, as well as for all causes.

It is recognized that classification of body build based upon height and weight alone is not completely adequate. Nevertheless, the range of variation of body weight at each height is great enough to provide significant differentiation between persons of various builds. Moreover, this classification is virtually the only one for which a substantial volume of long range data on longevity is available.

SPECIALIZED MORTALITY INVESTIGATION

The *Specialized Mortality Investigation* ('03) covered the experience of 34 companies on 98 special classes of male risks who were insured at standard premium rates after 1869 but before 1900 and traced to the policy anniversary in 1900. The mortality table used in the computation of mortality ratios was based on an English life table which was not altogether suitable because it understated the mortality ratios at the younger ages. Nevertheless, the facts in this study are instructive. There were several classes in which body build was a factor. Among the obese, the mortality was significantly above the expected except at entry ages 15 to 28. Among those with a lesser degree of overweight, the mortality ratios were generally lower than among the obese. In classes concerned with average and underweight persons, the observed mortalities were all generally below the expected.

MEDICO-ACTUARIAL MORTALITY INVESTIGATION

The *Medico-Actuarial Mortality Investigation* (vol. 2, '13) analyzed in great detail the effect of mortality in relation to build. Among males the unadjusted mortality ratios in detailed classes showed a fairly consistent downward trend in the ratios with advancing age for underweights and to some extent in those for average-weight men. The trend of ratios begins to shift upward by age among those slightly overweight and this was distinctly so in the case of those 15 to 20 pounds above average weight. The trend was not consistent by age in the group 25 to 30 pounds above average, but, except at the oldest ages at issue, the mortality ratios in this group were consistently above 100%. It was clear that at ages under 35 at issue the mortality figures favored those who were slightly or moderately overweight, but this did not hold true at ages beyond 35. At most ages from 35 up to about 55, the lowest mortality ratios were recorded among men 5 to 10 pounds underweight and, at ages 57 to 62, among those 15 to 20 pounds underweight. The highest ratios were generally of the order of 15 to 25% in excess of the standard, but if the class with the lowest mortality ratio is used as the base, the mortality among overweights after ages 35 ran from 30% to more than 40% higher than the minimum in the various age groups up to 56. In the oldest age group, 57 to 62, it was approximately 50% higher.

Attention was paid in this study to the causes of death according to build, but unfortunately the material considered only three broad classes, namely, those 50 pounds or more overweight, those 25 pounds or more underweight, and the group between, designated as "Standard Lives." Nevertheless, certain findings are of significance. At ages 15 to 29 at entry the highest mortality was recorded in the underweight group, and was primarily due to the mortality from tuberculosis which accounted for nearly 40% of the deaths. Even in this young age group, however, overweights had the highest mortality from diabetes, cerebral hemorrhage and apoplexy, heart disease, cirrhosis of the liver and Bright's disease. At ages 30 to 44 at entry overweights showed much the highest death rate from all causes and also from diabetes, all the cardiovascular-renal diseases and cirrhosis. The rates for the obese from the cardiovascular-renal diseases averaged more than four times that among the underweights. In this age group tuberculosis was the major cause of the small excess in the death rate of underweights as compared with overweights. At ages 45 and over the crude mortality rate was least in the underweight group and highest among the obese. The excess was most marked for diabetes where the rate among the obese was 20 times that among underweights. For cardiovascular-renal diseases, the crude death rate among the obese averaged more than double the figures recorded for the underweights.

Attention was also given in this study to the excess of abdominal girth over chest girth in relation to build (*Medico-Actuarial Mortality Investigation*, vol. 4, '14). The findings were not altogether consistent although it is evident that the mortality experience on obese men with large abdominal girth was very poor. Part of the inconsistency in the findings is believed to be the more rigorous selection of cases with excessive abdominal girth who were accepted for standard insurance.

The *Medico-Actuarial Mortality Investigation* also covered variations in the mortality experience according to body weight for females (vol. 2, '13). The number of lives was much smaller than for men, but in general, the characteristics of mortality by build paralleled that found among men; namely, at the younger ages, the record was least favorable among underweight and at the older ages was most favorable among them. In the overall picture the overweights had the highest mortality.

MEDICAL IMPAIRMENT STUDY, 1929

The next major intercompany study of build in relation to mortality was made in connection with the *Medical Impairment Study, 1929* for which the height-weight data were given previously. The mortality study was limited to males (*Supplement to Medical Impairment Study,* '32). It included those who were substandard risks on account of build. It covered the experience during 1909-1928 on those insured from 1885 to 1927. The general characteristics of build in relation to mortality found in the *Medico-Actuarial Mortality Investigation* still prevailed, namely, the mortality record was slightly unfavorable among young adult underweights, but at the older ages this group did best. In contrast, the mortality among the obese was highest in all age groups.

The high mortality among the overweights is thrown into better relief if comparison is made on the basis of the weight group with the lowest mortality ratio. The details are shown in table 1. Thus, it is found that for those 25% or more overweight, the mortality ratios were generally one and a half times that of the weight group with lowest mortality.

Analysis of the causes of death in this experience was made on the same basis used in the *Medico-Actuarial Mortality Investigation*. Because of the inclusion of a very large number of young lives, these data at ages 10 to 29 are atypical and are therefore omitted from this discussion. At ages 30 to 44 the mortality was the highest among overweights, due

TABLE 1

Medical impairment study, 1929

Observed ratios of actual to expected mortality among male overweights and estimated ratios based upon mortality in "optimal weight" group

Experience of 32 life insurance companies, 1909 to 1927 by deviations from average weight and by age groups at issue

AGE GROUP AT ISSUE: Percent above average weight	PERCENT ACTUAL OF EXPECTED DEATHS Observed	Estimated on basis of mortality in "Optimal weight" group *
Ages 20–29		
5% to 14%	99	106
15% to 24%	107	115
25% to 34%	134	144
35% or more	163	175
Ages 30–39		
5% to 14%	90	107
15% to 24%	120	143
25% to 34%	137	163
35% or more	137	163
Ages 40–49		
5% to 14%	97	126
15% to 24%	117	152
25% to 34%	141	183
35% or more	141	183
Ages 50–59		
5% to 14%	91	115
15% to 24%	118	149
25% to 34%	122	154
35% or more	143	181

* Ratio in weight group with lowest mortality
Ages 20–29—93%
30–39—84%
40–49—77%
50–59—79%

primarily to the cardiovascular-renal diseases and diabetes. In the underweight group the small excess of the death rate over that of standard lives is more than accounted for by tuberculosis. At ages after 45 the crude mortality was lowest among underweights and highest among overweights, and all but a small part of the excess of the mortality among the obese was due to the cardiovascular-renal diseases and diabetes. The mortality rates were all distinctly lower in this study than in the *Medico-Actuarial Mortality Investigation*, but significantly, the greatest improvement was in the respiratory diseases, especially among average and underweights, where not only the actual mortality was lowered but also the proportion of total deaths due to these causes.

Investigation was made also of the mortality among cases with abdominal measurements more than two inches greater than chest girth at full expansion. In all cases the mortality was elevated, seriously so in those markedly overweight.

STUDIES MADE AFTER 1929

In the years since 1929 we have witnessed the virtual abolition of deaths from tuberculosis among the better situated classes in the community, and in all classes, radical reduction in mortality from infectious diseases, notably pneumonia. While the mortality from these conditions still tends to be higher in underweights, their importance relative to the total mortality has diminished so greatly that when the trend in the mortality from all causes combined is considered, it is so greatly in favor of underweights as to wipe out even at the younger ages the differential in mortality that was formerly in favor of overweights. This has been brought out in a number of studies of the experience of individual companies made in recent years (Dublin and Marks, '37 and '38; Blair and Haines, '49; McCormick, '49).

A comprehensive investigation was made of the mortality experience on women according to build among those insured by the Metropolitan Life Insurance Company between 1922 and 1934 and traced to the policy anniversary in 1936 (Dublin and Marks, '37 and '38). This study showed the same trends as earlier studies on male lives, namely, relatively high mortality among young underweights; distinctly high mortality among old overweights; the most favorable build for mortality shifted from moderate overweight at the younger ages to moderate underweight at older ages. Some evidence was found that the excess mortality at both extremes of the weight scale was not as great in females as in males.

For tuberculosis the mortality was much higher than average among underweights and decreased with increasing weight. Among young underweights, the mortality from pneumonia and influenza was likewise higher than average for those markedly underweight. For the chronic cardiovascular-renal diseases there was a fairly steady progression of the ratios from the lowest levels in the underweight groups to the highest in overweight groups. The most striking differences were found in diabetes and diseases of the gallbladder and biliary passages. For these the upward progression of the mortality ratios with increasing weight was marked.

A special study of the mortality among very tall men showed that with respect to the relation of build to mortality these men were no different from their shorter fellows (Dublin and Marks, '36). This study, based upon the experience of the Metropolitan Life Insurance Company in 1922-1935 on men at least 6 feet 2 inches tall showed a generally higher mortality among those who were overweight than among the underweights. This was especially marked among the older men, and for them particularly the excess mortality was due principally to degenrative cardiovascular-renal diseases.

A study was made of the Metropolitan's experience on persons limited to substandard insurance solely on account of weight who were insured in the period 1925 to 1934 and traced to the insurance anniversary in 1950 (Dublin and Marks, '52). This experience covered more than 50,000 persons—26,000 men and 25,000 women. The mortality of these overweights was measured by the comparable experience for each sex among persons accepted for standard insurance. The adverse effect of overweight was evident at every period of adult life and increased with the degree of overweight.

Again, a better measure of the excess mortality of these overweights is to compare it with that of the weight group with the lowest mortality. For this purpose contemporaneous data were not available. Accordingly, the ratio for the "optimal weight" group of the *Medical Impairment Study, 1929* was used as a standard. Computations for males on this basis, given in table 2, indicate that the mortality ratio among the overweights in the new study was of the order of 200% at ages 20 to 50 and 165% at ages 50 to 59.

The excess mortality of the overweights in this study also was primarily accounted for by the high death rates from the diseases of the cardiovascular-renal system, diabetes, and liver and gallbladder disorders. Both sexes showed the same general picture.

TABLE 2

Mortality among males limited to substandard insurance because of overweight

Observed ratios of actual to expected deaths and estimated ratios on basis of mortality in " optimal weight " group

Experience of Metropolitan Life Insurance Company, Ordinary Department, issues of 1925–1934, traced to policy anniversary in 1950

AGE GROUP AT ISSUE	PERCENT ACTUAL OF EXPECTED DEATHS	
	Observed	Estimated on basis of mortality in " optimal weight " group *
20–29	180	194
30–39	169	201
40–49	152	197
50–59	131	166

* According to ratios in weight group with lowest mortality in *Medical Impairment Study, 1929.* For details see footnote to table 1.

EFFECT OF WEIGHT REDUCTION ON MORTALITY

It was possible in this study to segregate those overweights who had lost enough weight to have their rating removed and to analyze the mortality record for them. It was found that weight reduction improved the outlook for these cases. For example, among men originally limited to Substandard insurance because they were moderately overweight, the mortality subsequent to the change of rating was 113% of the standard, compared with a mortality ratio 142% for all the moderately overweight men.

MORTALITY AMONG OVERWEIGHTS IN RELATION TO SPINE LENGTH AND CHEST GIRTH

Since insurance physicians and actuaries have been well aware that many overweights, even some of the obese, live to a ripe old age, it is not surprising that search has been made for some simple means of identifying the "good" overweights. All these attempts have been fruitless. The major study along these lines which was thought to have great promise was based upon the criteria of physical fitness developed by Dreyer ('21), according to which a relatively long trunk appeared to be advantageous. Fortunately the Union Central Life Insurance Company had required measures of the length of the trunk of applicants. This provided the only source of data based upon a considerable volume of experience that would approximate Dreyer's criteria. Preliminary studies were made to set up the necessary standards of relative spine length according to height and age (Dublin, '23). Tests of Dreyer's criteria were applied to employees of the Metropolitan Life Insurance Company. The criteria were not successful in discriminating between the healthy and the unhealthy employees. Nevertheless, a full-scale study was conducted to test the hypothesis by the long term mortality experience on the Union Central Life Insurance Company's male policyholders (Dublin, '24 and '25). The results were rather contradictory and confusing. Tall overweights with long trunks had a somewhat lower mortality than other overweights, but this did not hold for shorter men. The only positive finding was that overweights with large chest girths had a higher mortality than the others. One may suspect that this might simply have reflected a somewhat higher average weight for the group.

MODIFICATIONS OF STANDARD WEIGHT TABLES

The evidence then is overwhelming that overweight is dangerous for health in many ways, and the shortening of life associated with it is a serious matter. Moreover, the standard of weight in middle and old age is much too generous. Suspicion about this goes back longer than is generally realized. As early as 1908 Dr. Brandreth Symonds, one of the great figures in life insurance medicine of his day, raised the question and again brought it up in his presidential address at the meeting of the Association of Life Insurance Medical Directors in 1912 (Symonds, '15). Accordingly, a resolution was passed by the Association requesting the Subcommittee in Charge of the Medico-Actuarial Investigation to work with the Actuarial Society to produce a table of weights which corresponded with the lowest mortality. We find this matter of the best weight a recurrent theme in the deliberations of life insurance medical directors and the actuaries. In 1920 Arthur Hunter, the Actuary of the New York Life Insurance Company, spoke before the Actuarial

Society on the topic "Is the Average the Same as the Normal for Weight and Blood Pressure?" His paper contains a table of "normal" weights, using the lowest mortality as a gauge, for men of average height.

Over the years there was mounting criticism of the weight tables in common use in that they ignored the disadvantages of the increase in weight with advancing age, as well as variations in bodily proportions and other factors that influence the weight of individuals. Among the attempts to satisfy this deficiency was the construction of desirable weight tables (originally designated "ideal weight" tables) for men and women by the Statistical Bureau of the Metropolitan Life Insurance Company in 1942-1943. These tables apply to all adult ages 25 and over. They are primarily based upon adjusted values of the earlier standard tables. Rather arbitrary assumptions were made in devising these tables, because of the lack, which existed then and still exists today, of more exact criteria for use in constructing tables of this kind for common use. The tables of desirable weight are generally adequate for the purpose for which they were designed, but further study of the matter is needed.

Concern about weight standards is greater today than ever before because, as the germ enemies of mankind have been nearly annihilated and the proportion of persons surviving to middle and later life has greatly increased, the chief problem in the field of health is control of the cardiovascular diseases which now account for the majority of deaths. Of particular concern are the high rates prevalent among men in their productive years. Much of this represents premature degeneration, and to that extent, efforts to prevent or slow down the process are eminently worthwhile.

SUMMARY

Life insurance records of body measurements on large numbers of men and women have been of value as the source of data for the construction of height-weight tables. Such data, collected at irregular intervals, indicate that average weights, specific for height and age, were fairly stable over long periods except at the younger ages. More current data of the kind are highly desirable.

Even more useful have been the studies of the relation of body build to mortality. The body build was characterized, principally, in terms of a deviation from the average weight for sex, age and height. The number of such studies is quite large. They include major investigations comprising the combined experience of all the major life insurance companies as well as more numerous studies of the experience of individual companies. The period of time covered by these various investigations spans the years from post-Civil War days down to the present. Despite the long period of time covered by the insurance investigations and the variety of sources of the data, they have shown consistently that excess weight is associated with decreased vitality and longevity. Furthermore, despite changes in medical concepts and terminology, the excess mortality was found, consistently, to be due to the early onset and relatively rapid progression of diseases affecting the circulation, the excessive frequency of diabetes, in which vascular breakdown occurs earlier than in nondiabetics, and of disorders affecting the liver and gall bladder. The implications of these findings with regard to the penalty of overweight are unmistakable.

It is clear that the standards of weight long in vogue in this country and still widely used are too generous. Consequently, modification of these tables is overdue. A new study of life insurance experience, now under way, will provide the basis for new standards.

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FAT THICKNESS AND GROWTH PROGRESS DURING INFANCY

BY STANLEY MARION GARN
WITH THE ASSISTANCE OF
GEORGIA R. GREANEY AND RICHARD W. YOUNG
Fels Research Institute,
Antioch College, Yellow Springs, Ohio

INTRODUCTION

THE human fetus, lean until late in prenatal life, accumulates fat at so rapid a pace thereafter that the newborn infant is notable among mammals for high fat content (Widdowson '50, McCance and Widdowson '51). Fat addition continues to be rapid, from birth until some time in the first year (Stuart *et al.* '40, Reynolds '51). Thus the one-year old, not necessarily at his fattest, is as fat percentagewise as the 50-year old male (Garn and Harper '55) and in many cases far exceeds 25% fat by weight (Garn, unpublished data).

The unusual fatness of the human infant probably represents an evolutionary adaptation to the thermoregulatory problems faced by the young of a glabrous wide-ranging homeotherm. While this explanation cannot be verified directly, it is true that adjustment to low temperatures is made easier by an adequate *tela adiposa*. Besides, there is experimental evidence that fat materially reduces heat loss in the infant, and thereby minimizes the total caloric requirements (Murlin '23, p. 645).

A second problem relating to the infant's fat concerns its mobilization, availability and usage. In adults, a large proportion of the stored fat appears to be available when needed. For older children there is evidence that the amount of fat stored is directly related to size and growth progress. From Czerny and Keller ('28) to Bruch ('39) to Fry ('53), findings agree that fatter children tend to be somewhat taller, advanced in skeletal development, earlier in attaining sexual maturation, dentally advanced and that they tend to excrete amounts of urinary 17 ketosteroids above the average for their age (Talbot '45, Talbot, Sobel, McArthur and Crawford '52). Whether the larger size and more rapid growth progress of obese children is attributable to "functional hyperpituitarism secondary to caloric hypernutrition," as Talbot puts it, is not certain. But the demonstrable relationship between the amount of stored fat and size and growth progress in childhood makes the fat a useful indicator of the "nutritive state" at that time (*cf.* Batkin '15 and later authors).

But what is the situation in infancy? How do size and growth relate to the amount of fat? Here comparable data have been lacking, to the best of our knowledge. Though there are large individual differences in the amount of fat stored by infants, it is not known for certain whether or not these differences are paralleled by comparable variations in size and growth (as in childhood). It is the purpose of the present study to examine this problem.

METHODS AND MATERIALS

The present study is based upon serial anthropometric and roentgenogrammetric data on over 300 White infants at 1, 3, 6, 9, and 12 months. All were born in Southwestern Ohio, generally to Ohio-born parents of northwestern European ancestry. Twins and triplets and infants weighing less than 2500 grams at birth were excluded from the tabulations, as were infants with congenital defects. Acutely-ill infants and those recovering from illness were not included, since such individuals are not ordinarily brought to the Fels Institute at the time of a regularly scheduled appointment (*cf.* Robinow '42, p. 159). The group then consists of clinically healthy White infants, with the developmentally immature weeded out.

Besides length (recumbent crown-heel length) and weight (nude) the following measurements were made on standardized antero-posterior roentgenograms of the left lower leg: tibial shaft length, maximum muscle breadth, and the combined medial and lateral subcutaneous fat-plus-skin thicknesses. In addition to the group means, computed in the usual way, size increments were calculated on an individual basis, for each measurement for each child.

Tibial length was selected as an index of long-bone size and growth. This measurement was taken as the maximum extent of calcification visible along the diaphysis, excluding epiphyses when present (see Maresh and Deming '39, Maresh '43, Kelly and Reynolds '47). Though there are advantages to measuring the fibula instead of the tibia (Day and Silverman '52, Silverman, Day and Blodi, '51) the tibia is more easily measured in the standardized A-P view. However, the two bones yield closely related though obviously not identical results (Maresh '43).

Muscle size was measured as a simple diameter: the *maximum* diameter of the calf muscle shadow at right angles to the tibial shaft. This diameter overestimates but is highly correlated with the computed true cross-section area. The measurement of muscle size used by Reynolds in 1944, namely, "the combined breadth of the two muscle masses on each side of the two bones" (Reynolds '44, p. 184) was not employed both because it underestimates the true cross-section area and because slight errors of rotation markedly affect the obtained diameter. Similarly the technique of measuring the entire lower-leg muscle area, either by cutting out and weighing the muscle "shadow" (Stuart *et al.* '40), or by planimetry (Suarez '52, p. 202) was not utilized here because the so-called "total muscle area" of the lower leg includes much that is not muscle.

The subcutaneous fat thickness, measured as described by Garn ('54), is the sum of the two separately measured diameters, medial fat (*mf*) and lateral fat (*lf*). Since sex differences in the relative size of the two deposits are not as marked in infancy as they are in adults (*cf.* Garn and Saalberg '53), combining the two values helps to minimize errors due to medial or lateral leg rotation. While averaged values could be used instead of the total reported here (*mf* plus *lf*), averaging simply divides the total by a constant, and therefore constitutes superfluous computation.

The question of enlargement, sometimes incorrectly called "distortion," has been raised in discussing radiographic measurements of this kind. Since the tube-to-film distance is constant and part thicknesses do not vary greatly, the raw measurements can be used without correction. Even if full corrections are made for variations in part thickness, which affect only the distance anode-to-median-plane, they are surprisingly small.[1] In the present study the enlargement ratio averages 102% at 1 and 3 months, and 103% at 6, 8 and 12 months. The correction factors are therefore 0.98 and 0.97 respectively. The difference (0.01) is of no practical importance in this work.

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[1] The enlargement ratio is D_1/D_2 when D_1 is the anode-to-film distance and D_2 is the anode-to-median-plane distance (see Kemp, '51). The correction factor is the reciprocal of the enlargement ratio. In the present study D_1 is 914 mm and D_2 varies from 900 to 880 mm, depending on part thickness.

Throughout this paper reference is made to the leg muscle diameter and to the leg fat thickness. The reader is cautioned against extrapolating from these measurements to changes in tissue composition in the body as a whole. For, when all body components are in process of rapid change as they are in infants, a marked increase in the size of a given tissue layer may actually represent a *decrease* in the percentage contribution of that tissue to the body. Similarly, failure of a measured thickness to increase on the average does not necessarily mean that the tissue in question has failed to increase in the body as a whole. Estimates of changes in body composition have been made from the present data and will be reported in a separate communication.

TABLE 1

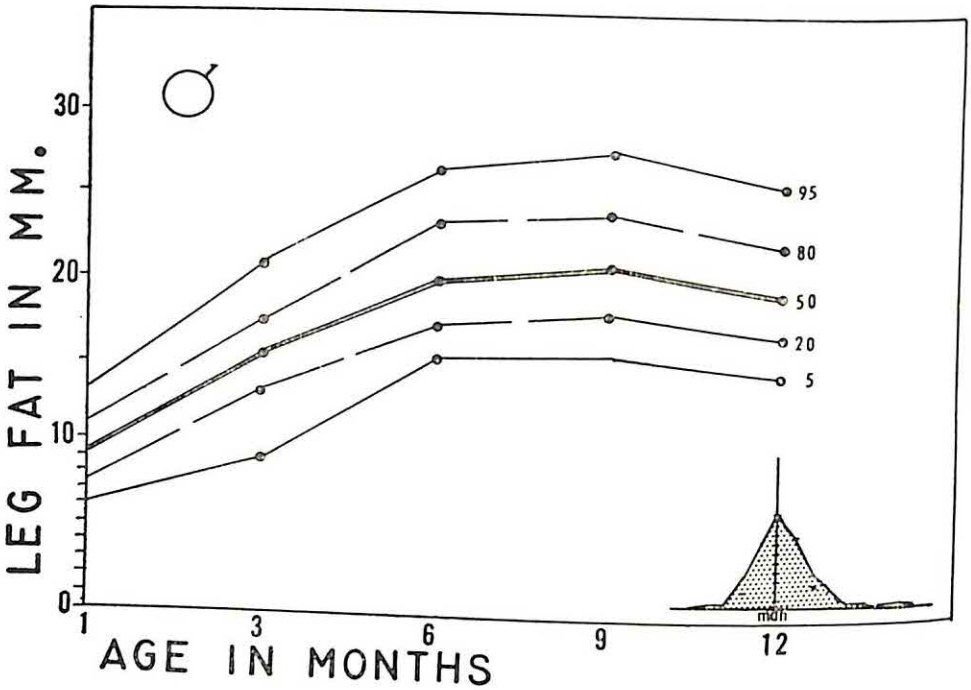
Leg fat thicknesses and leg fat increments for boys and girls aged 1-12 months

AGE	SEX	FAT THICKNESS PERCENTILES				
		5	15	50	85	95
1 mo.	Boys	6.2 [1]	7.8	9.5	11.3	13.3
1 mo.	Girls	6.3	7.7	9.6	11.8	13.7
3 mo.	Boys	9.2	13.2	15.7	17.7	21.0
3 mo.	Girls	11.4	13.4	15.4	18.5	19.4
6 mo.	Boys	15.3	17.2	20.0	23.3	26.6
6 mo.	Girls	14.8	17.2	19.8	23.2	26.0
9 mo.	Boys	15.8	18.2	21.0	24.0	27.9
9 mo.	Girls	15.6	17.7	20.7	24.5	27.3
12 mo.	Boys	14.6	16.9	19.3	22.1	25.6
12 mo.	Girls	13.9	16.5	20.5	23.1	27.8

AGE	SEX	FAT INCREMENT PERCENTILES				
		5	15	50	85	95
1–3 mo.	Boys	1.9 [2]	3.7	5.7	7.4	9.3
1–3 mo.	Girls	2.8	4.2	5.7	7.4	8.8
3–6 mo.	Boys	0.5	2.4	4.5	7.2	9.2
3–6 mo.	Girls	0.9	2.8	4.7	6.7	10.6
6–9 mo.	Boys	—2.0	—0.6	0.8	2.3	4.1
6–9 mo.	Girls	—3.3	—0.5	0.7	2.5	4.2
9–12 mo.	Boys	—4.1	—2.8	—1.3	0.3	2.5
9–12 mo.	Girls	—3.8	—2.3	—0.9	0.8	3.5

[1] Combined medial and lateral leg fat in mm.

[2] Increment in mm.



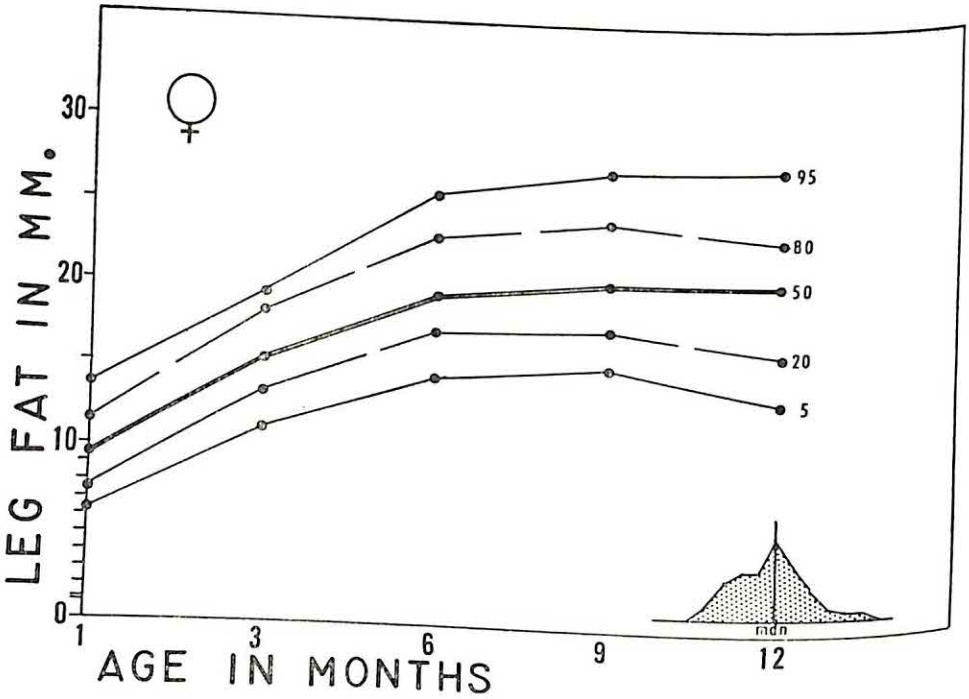


FIG. 1. Changes in the thickness of the subcutaneous fat on the lower leg from the 1st to the 12th month after birth. The heavy represents the median value, the lighter lines indicate the 5th, 20th, 80th and 95th percentiles. In both sexes the group trend is toward rapid accumulation of fat from the 1st to the 6th month.

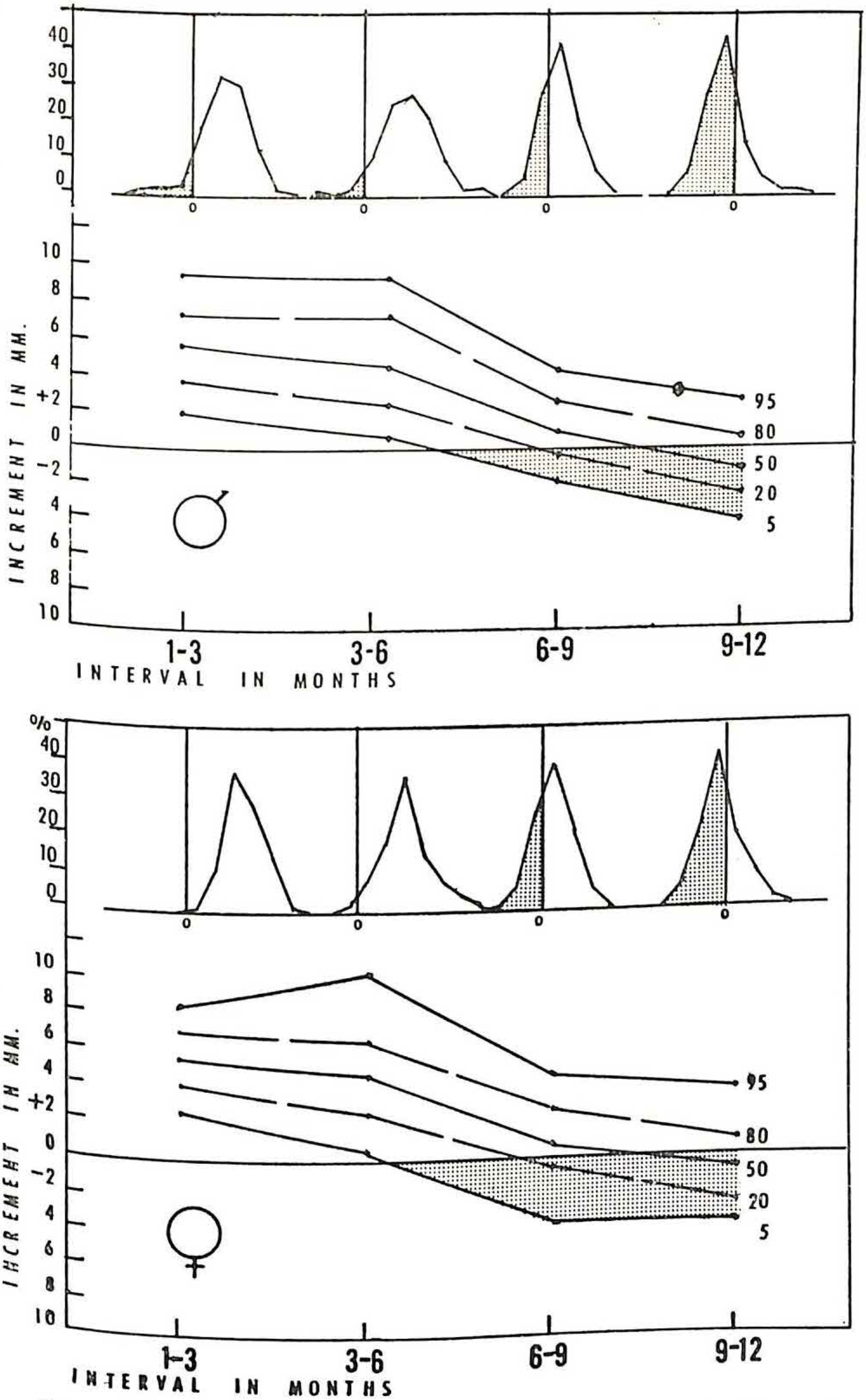


FIG. 2. Fat increments during the first year of life. Up to the 6th month all infants gain leg fat. Between the 6th and 9th month a minority have begun to lose; the majority are still gaining. Conversely between the 9th and the 12th month the majority lose fat. Compare this figure, based on individual *increments*, with the mass-data trends shown in figure 1.

FINDINGS

As shown in table 1, and pictured graphically in figure 1, the thickness of the subcutaneous fat on the lower leg increases rapidly during early infancy. From the first to the sixth month the median fat thickness doubles, rising from approximately 9.5 mm to 19.9 mm in both sexes. The rate of increase is 2.0 mm per month. But, between the sixth and the ninth month, the percentile values change but little, the total increase being 1.0 mm, and the rate of deposition 0.3 mm per month. Finally, between the ninth and the twelfth months, the median drops slightly both in boys and girls (table 1). At all 5 age levels considered the fat distributions are skewed, with the degree of skewness varying from month to month. Thus percentiles as employed in this study are more appropriate than the more commonly used means and standard deviations. Further, in comparing fat and lean infants the series is divided at the median rather than at the arithmetic mean.

While the fat thickness percentiles given in table 1 correctly show the rapid increase in lower leg fat during the first half year, they incorrectly suggest little change in subcutaneous fat during the remainder of the first year of life. The fat increments, computed on an individual basis tell a different story. As shown in the second half of table 1, and in figure 2, the period 1–6 months is characterized by a general fat increase. But, between 6 and 9 months (when the majority of boys and girls are still gaining fat) a minority have begun to lose fat: the two trends partially balance each other and thus the median remains nearly constant from 6 to 9 months. Again, between 9 and 12 months, the majority of infants lose lower leg fat (up to 6.0 mm) while a minority are still gaining. Thus fat change is considerable during the second half of the first year, but the changes occur in both directions.

During the first year there are large individual differences in the amount of fat on the lower leg, though sex differences in thickness (not in percentage fat) are negligible. The fattest 5% of infants have nearly twice the combined lower leg fat thickness of the leanest 5% at 1, 3, 6, 9 and 12 months. Since individual differences in the amount of fat are of such a magnitude, it is of interest to determine whether they are associated with differences in length, in muscularity, or in the rate of growth.

Comparing the fatter infants (those in the third and fourth quartiles for fat) with the leaner infants (those in the first and second quartiles) it is obvious that the former enjoy a considerable size superiority at one month. As shown in table 2 and again in figure 3, the fatter male infants average 1.3 cm longer than the leaner ones; the medians for the two groups correspond to the 65th and the 37th percentiles, respectively. Similarly, the fatter female infants exceed the leaner ones by 1.1 cm, and the medians correspond to the 56th and the 40th percentiles respectively. (Both differences are significant at the 5% level or better, by the χ^2 test). But after 1 month of age comparable differences no longer exist. The differences present at 3, 6, 9 and 12 months do not

TABLE 2

Length and muscle size of leaner children (Q_1 and Q_2) and fatter children (Q_3 and Q_4 during the first year of life

		CROWN-HEEL LENGTH		TIBIAL LENGTH		LEG MUSCLE DIAMETER	
AGE	GROUP	Mean (mm)	Percentile	$\bar{X}$ (mm)	Percentile	$\bar{X}$ (mm)	Percentile
1 mo.	Boys Q_1 and Q_2[1]	54.0	37	72.2	37	31.9	43
	Boys Q_3 and Q_4[2]	55.3	65[3]	74.2	60[4]	32.7	54
	Girls Q_1 and Q_2	53.1	40	71.5	37	30.6	42
	Girls Q_3 and Q_4	54.2	56[4]	73.6	55[4]	31.6	61
3 mo.	Boys Q_1 and Q_2	61.3	52	84.3	43	36.2	44
	Boys Q_3 and Q_4	61.2	47	85.2	53	36.6	52
	Girls Q_1 and Q_2	59.6	47	83.1	43	33.3	40
	Girls Q_3 and Q_4	59.6	47	84.1	57	34.4	58
6 mo.	Boys Q_1 and Q_2	67.4	48	97.0	42	39.5	50
	Boys Q_3 and Q_4	67.8	55	98.5	53	39.8	53
	Girls Q_1 and Q_2	65.9	53	95.6	48	38.2	64
	Girls Q_3 and Q_4	65.9	53	96.2	52	37.1	44
9 mo.	Boys Q_1 and Q_2	72.0	41	107.0	47	43.5	55
	Boys Q_3 and Q_4	72.2	47	107.7	51	43.4	53
	Girls Q_1 and Q_2	69.8	46	105.2	44	43.4	63
	Girls Q_3 and Q_4	70.5	56	107.1	63	41.0	43[3]
12 mo.	Boys Q_1 and Q_2	75.7	46	116.2	44	47.7	54
	Boys Q_3 and Q_4	75.9	50	116.6	48	47.3	52
	Girls Q_1 and Q_2	74.0	49	114.7	48	47.5	57
	Girls Q_3 and Q_4	74.3	54	116.3	59	45.5	41

[1] First and second quartiles for fat.

[2] Third and fourth quartiles for fat.

[3] Difference significant at $P = .01$ or better.

[4] Difference significant at $P = .05$ or better.

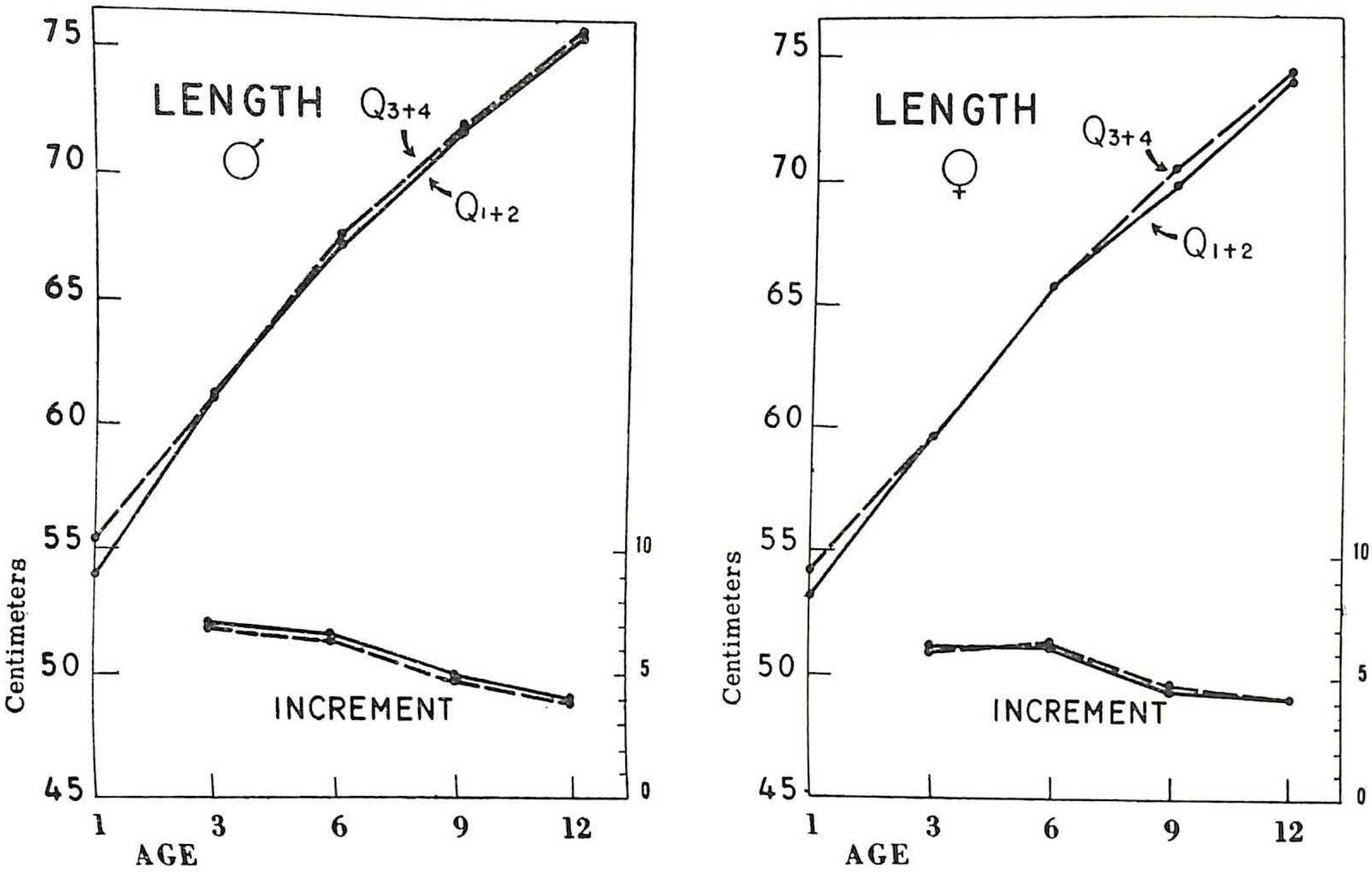


FIG. 4. Comparative length of fatter (Q_3 and Q_4) and leaner (Q_1 and Q_2) infants at 1, 3, 6, 9 and 12 months. The fatter boys and girls are significantly longer at one month, but not thereafter.

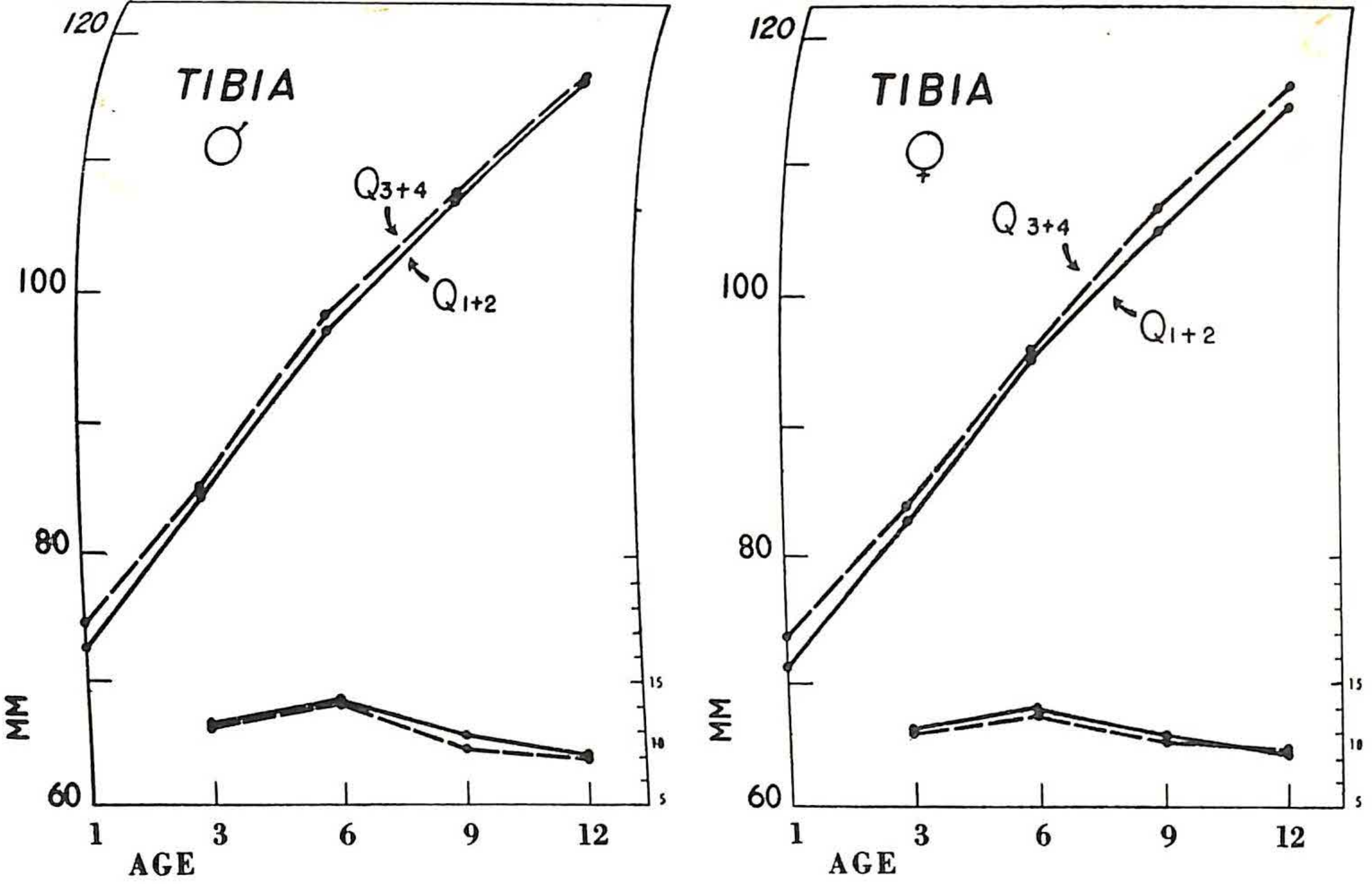


FIG. 4. Tibial shaft length of fatter (Q_3 and Q_4) and leaner (Q_1 and Q_2) infants. As with crown-heel length, the size superiority of the fatter infants attains statistical significance only at one month. (Each sub-group average 70–80)

attain statistical significance. Fat is associated with greater length at one month, in both sexes, but not beyond.

What holds for crown-heel length is true for tibial shaft length as well, thus eliminating the possibility that the initially greater length of the fatter infants is due solely to fat accumulation on the scalp and plantar surfaces. At one month the fatter boys, those in the third and fourth quartiles, are significantly longer in shaft length than the leaner boys. The fatter girls are comparably longer than the leaner girls in the extent of tibial shaft calcification at 1 month. But at 3, 6, 9 and 12 months the leaner and fatter moities are not significantly different from each other (table 2 and figure 4), even though a tendency toward slight superiority persists.

As contrasted with crown-heel length and tibial shaft length, muscle diameter does not differ significantly between lean and fat one-month-olds. With one exception, the 9-month old girls, there are no significant differences in muscle diameter between the fatter and leaner contingents and this single exception is in the reverse of the expected direction. However it should be noted in figure 6, as well as in table 2, that there is a tendency for the leaner girls to have larger leg muscle throughout the second half year. Initially the fatter girls enjoy an advantage which is not statistically significant and is not continued.

In general, then, the fatter infants exhibit a size superiority at one month, and not consistently thereafter. But the negative nature of these findings must be considered in terms of the two categories "fat" and "lean." With large individual differences in the tendency to gain or lose fat, especially during the sixth to twelfth month, it is possible for a child to be in the "fat" category at one age interval and not in another. What happens if infants initially fat, and others initially thin are followed for a full year? This has been accomplished by selecting boys and girls initially in the first quartile and the fourth quartile of the fat distribution at one month and determining their size and growth progress at 3, 6, 9 and 12 months.

As shown in table 3 and figure 6 the "fattest" (Q_4) and "leanest" (Q_1) infants differ considerably at one month. Those in the fourth fat quartile are markedly longer than those in the first fat quartile, exaggerating the trend previously noted. They also differ in muscle width, though to a less considerable degree. At three months the size gap between the "initially fat" and "initially thin" infants is narrower. At 6 months the differences are no longer significant at the 5% level,

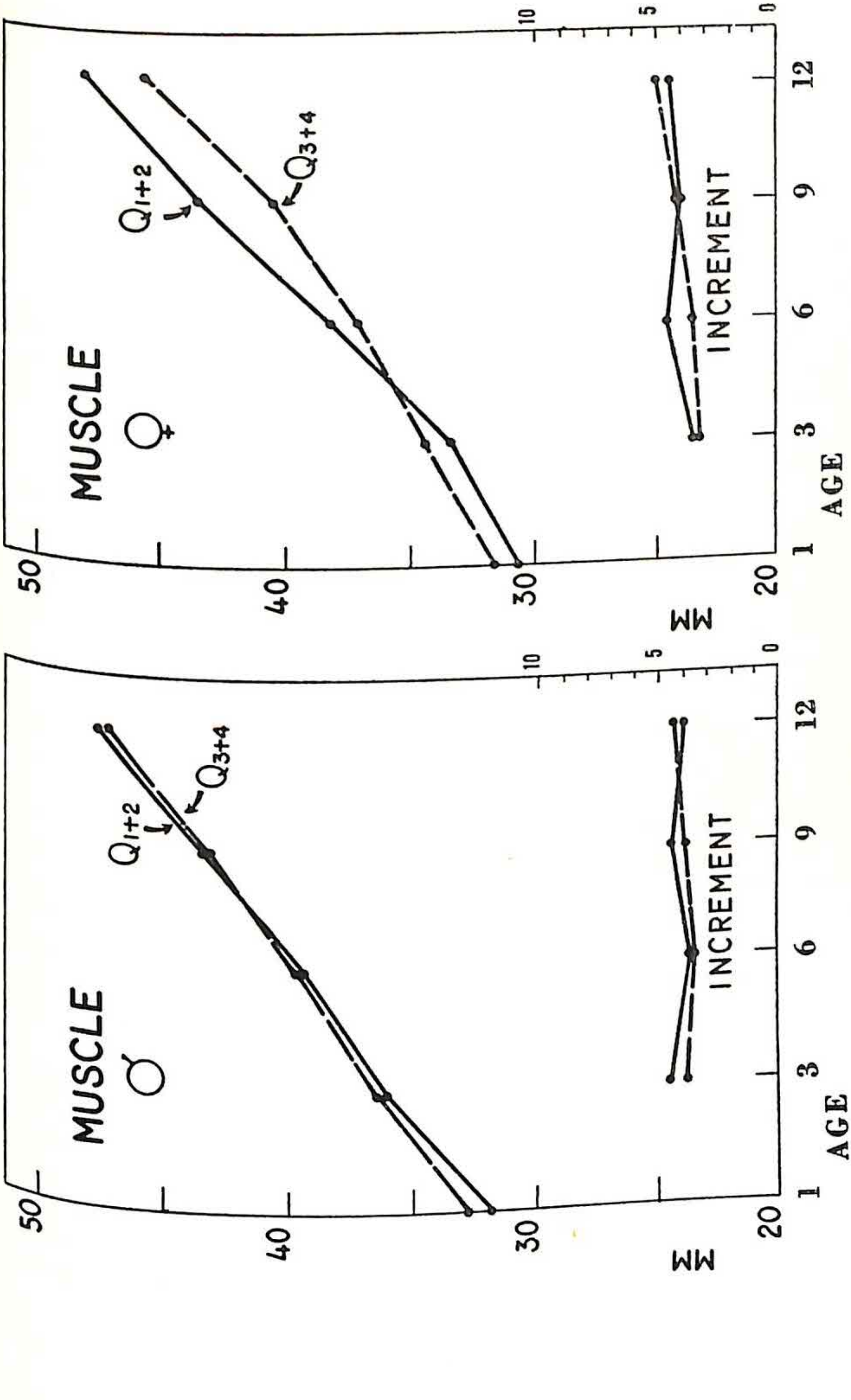


FIG. 5. Comparative transverse muscle breadths of fatter and leaner infants. There is a suggestion that late in the first year the leaner infants are endowed with greater musculature. This attains statistical significance only in the 9 month old girls.

and by 9 months there is crossing over in both sexes so that the initially thinnest boys and girls eventually have the broader muscles. The two groups, markedly different early in life, regress toward the mean, and become virtually identical by the end of the first year.

It would seem therefore that subcutaneous fat relates to length, size and growth progress early in postnatal life, but the advantage of being fat at one month, if any, fails to carry through the remainder of the first year.

TABLE 3

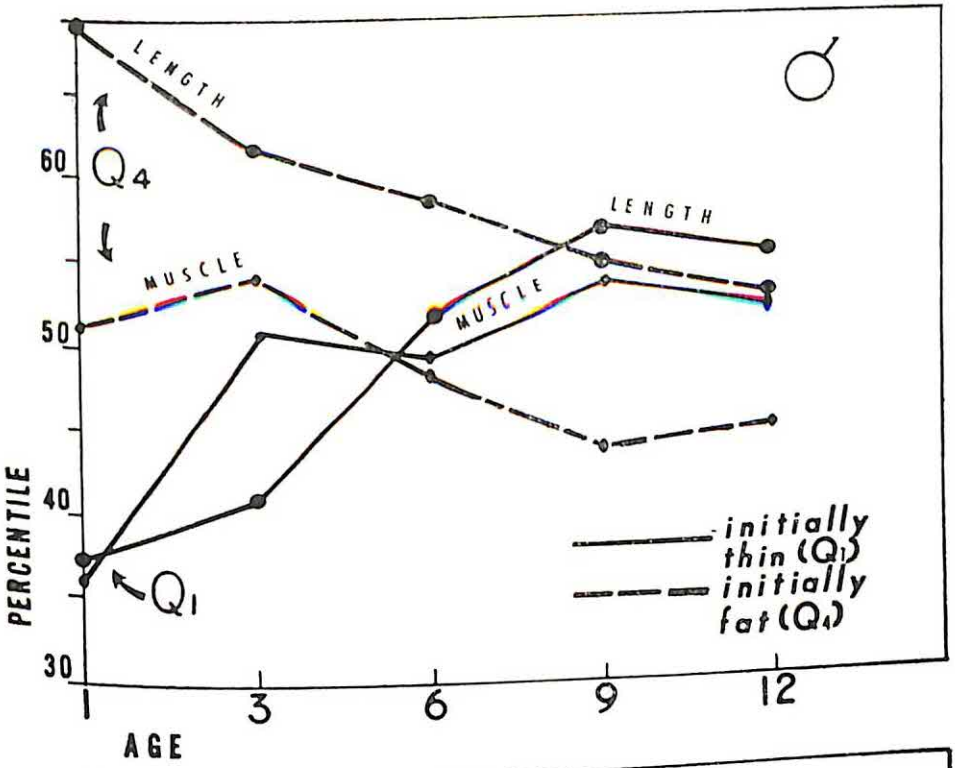
Comparison of mean length and muscle percentiles for initially thinner (Q_1) and initially fatter (Q_4) infants at 1, 3, 6, 9 and 12 months

		CROWN-HEEL PERCENTILES			MUSCLE PERCENTILES		
AGE	SEX	Q_1	Q_4	t[1]	Q_1	Q_4	t[1]
1 mo.	Boys	37.1	68.8	4.6	36.7	51.0	2.2
1 mo.	Girls	31.0	62.4	4.2	32.4	56.3	3.0
3 mo.	Boys	41.1	62.0	2.9	51.8	54.5	0.4
3 mo.	Girls	34.8	54.5	2.4	39.4	47.8	1.0
6 mo.	Boys	52.5	58.6	1.1	49.4	48.2	0.1
6 mo.	Girls	36.6	50.5	1.6	44.9	57.8	1.5
9 mo.	Boys	56.5	54.3	0.3	53.7	43.8	1.0
9 mo.	Girls	39.1	47.8	1.1	47.3	42.1	0.6
12 mo.	Boys	55.2	53.0	0.3	51.7	45.3	0.8
12 mo.	Girls	40.1	47.8	0.9	45.3	43.3	0.2

[1] For values for N represented in this table, the .05, .02 and .01 confidence limits correspond to t values of 2.1, 2.5 and 2.8 respectively.

DISCUSSION

The findings in the present study indicate that, with the exception of the first month of prenatal life, there is little demonstrable relationship between the amount of subcutaneous fat on the leg and the size and growth progress of the infant. Though there are large individual differences in relative fatness during the first year, and the more obese infants have more than twice the fat thickness of the leanest, the fatter infants are not uniformly longer or more robust and the leaner infants are not shorter or of more delicate growth. If body size (as apart from weight) and growth progress are used as operational measures of nutri-



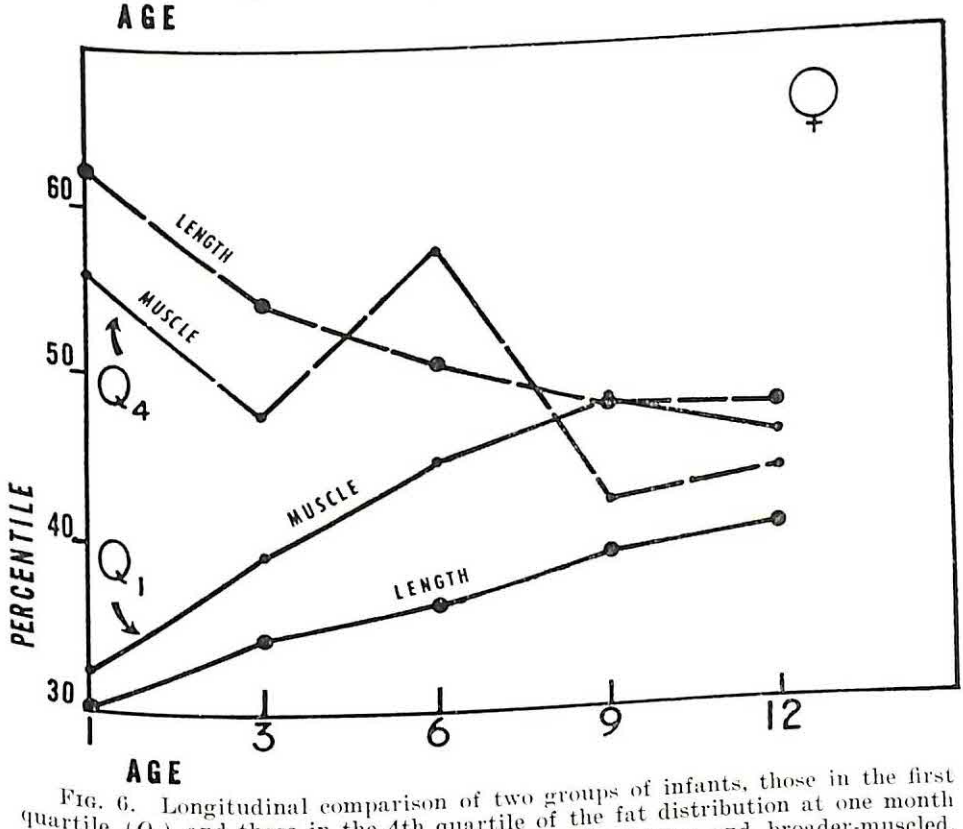


FIG. 6. Longitudinal comparison of two groups of infants, those in the first quartile (Q_1) and those in the 4th quartile of the fat distribution at one month (Q_4). The initially fattest infants are initially longer and broader-muscled. But the two groups converge. The differences are not statistically significant by the middle of the first year, and there is some evidence that the initially leaner infants develop more muscle.

tional status in healthy infants, then the amount of subcutaneous fat proves to be an uninformative index of the state of nutrition.

Moreover, the appreciably larger size of the fatter boys and girls at one month need not be attributed to a specific dynamic action of fat. Rather, analysis of the growth records of these fatter young infants show them to have been advanced, developmentally, at birth. The boys and girls in the fourth quartile for fat at one month weighed much more at birth (3.77 ± .07 kg and 3.62 ± .08 kg) than did the boys and girls in the first fat quartile at one month (birth weight 3.17 ± .08 and 2.92 ± .07 kg respectively). In other words the apparent relationship between fatness and size at one month, is due to the persistence at that early age of differences in size and fat content at birth. But despite this "head start" the initially fatter infants do not maintain their size superiority, and by the middle of the first year, group differences virtually disappear.

There remains, of course, the problem of why the subcutaneous fat behaves as it does during early infancy, and this problem includes both the rapid accumulation of fat at a time when energy requirements for growth are at their maximum, and the seeming failure of the stored fat to contribute to the general motion of growth. Though it is true that the infantile accumulation of fat represents a temporal continuation of a trend started during late uterine life, reiterating this observation provides no further insight into the mechanisms involved. Similarly, the truism that fat represents the difference between energy input and energy output does not explain how appetite and growth are synchronized to facilitate the rapid accumulation and deposition of fat during early infancy.

It should be noted that milk, which even in these days remains the major source of calories for the infant, is in effect a high-fat food. Depending on breed differences, cow's milk provides up to 60% of its calories in the form of fat, while human milk—slightly lower in fat—provides up to 50% of the available calories in this form.[2] Since high fat diets providing approximately 60% of the calories in the form of fat are capable of inducing massive obesity in experimental animals (Mickelsen *et al.*, '55) the similarity between milk and such high-fat diets should be observed. And further, there is the possibly relevant fact that in our material, the age at which infants often begin to lose fat is the age at which milk begins to play a decreasing role as the major source of calories.

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[2] Calculated from table 1 and page 20 in Bowes and Church ('51).

Again, there may be a hormonal explanation for the fat gain in early infancy. Without going into the question of a "pyknophilic" hormone, or such a secretion as "adipokinin I or adipokinin II" (*cf.* Weil *et al.*, '47) there is at least one parallel where rapid fat addition has an hormonal basis. This is during adolescence in the female, where subcutaneous fat is greatly increased (Reynolds '50). Here, as in the replacement therapy of the female with ovarian agenesis, feminizing hormones do serve to direct the mobilization and deposition of fat. It may well be that hormones like cortisone (which promotes fat deposition) are both responsible for the rapid fat accumulation during infancy, and for individual differences in the amount of fat added during the first few months of life.[3]

There is no question that the amount of fat does relate to size and growth progress and therefore to "nutritional status" during childhood. Again in the adult, fat and health are related, though now fat becomes negatively related to longevity. Seemingly it is in transitional periods that fat appears to be a less useful measure of nutrition partly because at such times the implications of a given amount of fat depend upon the level of maturity attained. Ten millimeters of trochanteric fat may be indicative of obesity (in a late maturing 12 year old girl); alternatively, it may represent leanness (in a sexually mature girl of the same age). Similarly at one month of age, 10 mm of leg fat is meagre for developmentally advanced babies and generous for physiologically younger infants.

The result obtained in the present study are not those we expected to find. Based on previous experience with children and adolescents, especially the "fat-pad" group reported by Fry ('53) and Peckos ('53) it seemed logical that fatter babies would be appreciably larger, distinctly more robust and developmentally well ahead. But this is not the case, in normal healthy infants. In such infants, suffering from no feeding disturbance or avoidable vitamin lack, the amount of fat is scarcely related to size and growth progress. Under these circumstances and within the restriction noted, it seems apt to repeat Batkin's ('15, p. 122) comment made 40 years ago, "We have no right yet to equate the thickness of the fat blanket with the state of nutrition: it is dubious whether we will have at some future time."

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[3] The possibility of a neural mechanism affecting the differential deposition of fat on the lower limbs during infancy should be considered. Unilateral motor nerve paralysis does cause unilaterally increased fat deposition in paralytic children (Garn and Silverman, '55), but the inference that increasing motor nerve activity causes loss of leg fat is still premature.

SUMMARY

1. The relationship between the thickness of the subcutaneous fat on the left lower leg, and size and growth progress in infancy was investigated in over 300 clinically healthy, presumably full-term infants at 1, 3, 6, 9 and 12 months of age.

2. As previously reported, subcutaneous fat increased rapidly in all infants from 1 to 6 months, doubling in median thickness. Thereafter, the tendency for some infants to gain fat while others were losing fat led to the appearance of stability as reflected by the "norms."

3. Comparing lean and fat infants, the latter were significantly longer at one month, but not thereafter. The same general trend was observed in tibial shaft length (extent of calcification along the diaphysis), whereas for muscle breadth the two groups did not show any consistent difference.

4. The initially leanest and intially fattest infants were markedly different at one month, but tended to converge and become indistinguishable thereafter.

5. The early and transient size superiority of the fatter infants at one month was shown to be a holdover from their superior size and developmental advancement at birth.

6. There was no evidence that the fatter infants were consistently more robust or faster growing, thereby questioning the use of subcutaneous fat as a measure of nutritional status in healthy infants during the first year of life.

7. Attention was drawn to the rapid accumulation of subcutaneous fat during the first part of the first year and the lack of satisfactory explanations for this phenomenon. The possible influences of high fat diet (which milk is) and of hormones directing the deposition of subsurface fat were considered.

8. In view of these findings, it was questioned whether—unlike childhood where fat and growth progress are related—the amount of subcutaneous fat can be used as a measure of nutritive status in otherwise healthy infants.

ACKNOWLEDGMENTS

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COMMENTS

Werner Kornfeld (New York Medical College, New York) made the following comment:

Nutritional anthropometry in children cannot be separated from a more general appraisal of body build and physical development. Different methods have to be applied in mass surveys, in research projects, and in pediatric practice. For different age groups different measurements have to be selected as minimum requirements. Out of a larger group of measurements which were used in studies made on children in New Jersey (Oesterreichische Zeitschrift für Kinderheilkunde, 10:71, 1954) the following measurements were selected as minimum requirements for the characterization of body build and physical development in infants: body length, stem length, body weight, head circumference, and chest circumference at two different levels (supramamillary and xiphoid). The advantage of taking these two measurements of chest circumference has been explained in an earlier publication (Journal of Pediatrics 42:715, 1953). A method of graphic illustration of the main features of body build based upon these measurements ("2/3 base line method") has been described (Journal of the Newark Beth Israel Hospital, Newark, N.J. 6:199, 1955).

In older children, after the fifth year of life, head circumference may be omitted. To characterize further the relation between longitudinal growth and circumferential growth in older children, inclusion of wrist circumference and of hand length are suggested.

For the special purpose of studying the soft tissue distribution the following measurements were used: circumference of forearm, arm and calf; skinfold measurements on the chest (infraclavicular), on the abdomen (lateral from the umbilicus), and on the back (medial from the inner margin of the scapula). Another measurement, characterizing the soft tissue masses in the cheeks, was obtained in the following manner: anthropometric calipers were used to measure the bizygomatic diameter (over symmetrical points of the most prominent part of the zygomatic arch), first without any pressure, avoiding any indentation of the skin, and then with moderate pressure towards the underlying bone structure. The difference between these two measurements gave a measure of the compressible or displaceable amount of subcutaneous masses in this region. It can be shown that this measurement follows rules in the normal development as well as in pathologic deviations which are different from those which govern the behavior of the skinfold measurements in the three regions mentioned above. Mean values obtained in different age groups for skinfolds and for soft tissue masses on the cheeks, and graphs demonstrating characteristics of soft tissue distributions in different age groups, are being prepared for publication in the near future.

R. F. A. Dean (Medical Research Council, Kampala, Uganda) referred to the studies of growth and development that are in progress in European and African countries, under the auspices of the International Children's Center in Paris, with support from the World Health Organization. The studies, which include somatotyping and anthropological measurements by the photographic method, all use the same techniques, so that the information obtained at the various centers may be truly comparable.

In Uganda, it has been found that the use of standards obtained from child populations in the U. S. A. and in European countries cannot be used on the African community without many reservations. There appears to be a different pattern of development in the African child: his height/weight ratio does not change in the same way as that of the U. S. child, and his bone age (as shown by x-ray examination of the hand) may, at early ages, be in advance, and not retarded as might be expected. The advance is paralleled by a precocity of psycho-motor development, and may be related to the early precise use of the hand and fingers.

Although there may be a dominant genetic control of the pattern of growth, as well as genetic control of final stature, there is undoubtedly some variation imposed by the plane of nutrition. The exact importance of nutrition is uncertain: it is being studied in Kampala, where a serious degree of under-nutrition may be present in a high proportion of children. Similar work would be difficult in the U. S., but there it should be possible to study different racial groups, to determine whether or not the development of the children in these groups follows the usual U. S. pattern.

ALLOMETRIC GROWTH OF BODY COMPOSITION IN MAN AND OTHER MAMMALS

BY EDWARD E. HUNT, JR. AND EUGENE GILES

Adolescent Unit, Children's Hospital and the Forsyth Dental Infirmary for Children, Boston, Massachusetts

An important development in the recent study of human biology has been the measurement of body composition in the living, and the literature in this field is now voluminous. Enough is known of the composition of young American White men to permit the tentative definition of a "reference man" of average weight for stature, and aged 25 years (Keys and Brožek, '53). The composition of women and children, however, is less fully known, and the present paper is a preliminary attempt to work out developmental trends in a few body constituents in both sexes.

The basic techniques of measurement in the study of body composition *in vivo* include the determination of density ("densitometry"), and the estimation of body water content by the dilution of foreign substances in the blood and other fluid compartments ("hydrometry"; *cf.* Brožek, '54). When both water content and density are measured on one occasion, the fat content of the organism can be determined with appropriate allowance for varying hydration, which may be an appreciable source of error in measuring fat from densitometry alone.

With reference to total body weight, the water content of man shows considerable individual variation. This variation is roughly the inverse of body fat content because adipose tissue contains far less water than does the remainder of the organism. But even with reference to the fat-free weight, hydration shows some variation in man (Bass, '54). This variation makes the determination of the individual fat-free weight uncertain from the weight of water alone, but such errors are less critical when group trends are calculated on reasonably normal subjects. Finally, the errors of measurement themselves are fairly large in at least some of the current hydrometric techniques.

Despite these difficulties with the hydrometric method, it is a logical starting point in extending the measurement of body composition in the living from men to women and children. The findings from this initial attempt can later be compared to those based on other known methods in this field. This array of analytical procedures might include such diverse measures of fat as the dilution of fat-soluble indicators, densitometry, and skinfold thicknesses. Determinations of fat, muscle and bone are possible from radiographs, and perhaps significant relationships between these tissues and metabolism can be established.

Underlying any secure methodology in the study of body composition is the chemical analysis of carcasses, whether growth studies are contemplated, or work on mature individuals. Some of the trends in the chemical growth of the animal body have been known since the pioneering work of von Bezold (1857), but much of the precise knowledge in this field is recent. For a few species of mammals, carcass analyses are numerous from the fetal period to maturity (Needham, '42). For man, however, although many analyses have been published of fetuses and stillborn neonates, few such studies are available on older individuals. Not much further progress on man can be expected unless this lack of data is overcome, or unless close analogies are demonstrated between lower mammals and the human species. Still another difficulty with human data is that the analyses have been based mainly on individuals who have died in a poor state of health, while the animal studies usually have been done on more normal specimens.

Despite the inherent limitations in the present study, we shall attempt to calculate normal growth trends of fat, water, and the aggregate of solids in the fat-free body (including minerals). Total non-fat solids plus water equal the fat-free body weight. "Extractable" fat is then the difference between total body weight and fat-free weight.

In his studies of the growth of the fat-free mammalian body, Moulton ('23) enunciated the concept of "chemical maturity." This phrase refers to the attainment of mature concentrations of water, protein and ash in the fat-free mass of the young animal. But as Spray and Widdowson ('50) have demonstrated, not all chemical constituents of the fat-free body attain their mature concentrations at the same chronological age. A more limited concept, to be used here, is the attainment of the young adult concentration of water in the juvenile fat-free body. One might speak of this stage as "aqueous maturity," or as we have done, "mature hydration."

In boys and young men, mature hydration can be defined from the composition of the "reference man" of Keys and Brožek ('53). In this standard, 70.9% of the fat-free body weight is water. The importance of discovering the minimum age of mature hydration in the male is that it defines a lower limit above which the prediction of other body constituents from water can be done by equations now available for young men. A parallel argument would apply to girls if a "reference woman" could be defined.

It is equally desirable to estimate the developmental changes in the water content of the fat-free body in children younger than the age of mature hydration. Much of the present paper is concerned with this problem, and where trends cannot be measured directly in man, comparable data are utilized from lower mammals. These estimations are based on the principle of relative growth or *allometry*.

THE ALLOMETRIC METHOD

The fundamental principles of allometry are to be found particularly in the treatise of Huxley ('32), who extensively developed and used the concept. Allometry is a mathematical technique for characterizing the relationships of size or concentration of two parts or constituents of the animal body (*cf.* Smith, '54, p. 120). In some instances the technique is applied to the percentage rate of increase of an organ or chemical constituent as compared to that of one of its parts. In other instances measurements of two distinct parts or constituents of the body are utilized. The symbols x and y are applied to the measurements, and in practically all allometric studies, the relationship between x and y is expressed by the following equivalent equations:

$$\text{Exponential } y = bx^k$$
$$\text{Logarithmic } \log y = \log b + k \log x.$$

The logarithmic form of the equation describes a straight line with slope k. Although time does not formally enter the allometric calculations, it is often convenient to think of k as a ratio between the percentage increases of x and y per unit of time. When $k = 1$, the increases of the two measurements maintain a proportional constancy, such that the constant $b = \dfrac{y}{x}$.

When $k > 1$, the percentage increase of y is more rapid than that of x, while when $k < 1$, the reverse is true. Where $k \neq 1$, the b coefficient is simply a suitable multiplier without any obvious biological significance.

Simpson ('53) has characterized the abundant literature on allometry. In paleontological studies, allometric equations may describe alterations of size and shape in an evolutionary lineage of organisms (lineage allomorphosis). Comparisons are also possible, without regard for time, among contemporaneous members of separate but related genera or species of animals such as the living anthropoid apes (Giles, '56). Within one species, one set of equations may fit the growth of immature individuals within empirically determined limits of size (heterauxesis), and another set may apply to the differences between small and large adults (individual allomorphosis).

Huxley ('32) showed that stable allometric relationships between the sizes of most body parts are often found in animal growth after the end of the embryonic period, when the major organs and tissues have become recognizable. The compilations of Huxley, and also of Needham ('42) indicate that it is generally more risky to extrapolate fetal allometric curves back into the embryonic period than forward into later growth.

The first applications of allometry to human growth were mainly based on fetal carcass analyses. Iob and Swanson ('38) calculated k values for a number of chemical constituents. Hamilton ('36) worked out a k coefficient for water and total dry substance (including fat) in the human fetus, and extrapolated his curve to the adult stage in order to estimate the water content of mature and aging human individuals. Needham ('42) published a large table in which water and dry substance were translated into allometric equations for many animal species, including man. His k coefficient for man applies from the fetal period to an adult weight of 66,000 g.

By combining data on fetal carcasses, living children and young adults, Forbes ('52a, '52b) found that the potassium and sodium concentrations of body fluids maintain allometric relationships with total body weight in older fetuses, children, and young adults. Forbes himself, and later Cheek ('54), found further allometric equations relating the chloride concentrations of body fluids and total body weight. The values of k for sodium and chloride are similar enough to suggest that an allometric "desalting" of the body occurs during growth. This loss, in turn, seems to indicate that the percentage of extracellular fluid in the human body correspondingly decreases.

Forbes ('52a) has also computed two allometric equations relating body water and total body weight. One applies to younger fetuses up to a weight of 373 g, and the other extends from 490 g to the mature weight of 84,800 g. In this instance, however, his results suffer from the fact that the weight of the body is largely water, so that one variable in both equations is incorporated into the other. When the incorporated variable is small, as potassium versus body weight, the conclusions are not greatly affected. But if the variable is large, as is true for water, the allometric method produces an artificially high correlation between log x and log y. The overlap of the two variables will also tend to obscure other important allometric relationships by necessarily inducing the k coefficient to approximate unity, as pointed out by Reeve and Murray ('42).

In the present study, this difficulty is met by separating water from total fat-free solids, and using them as the two variables in the allometric equations. This separation is intended to result in a biologically more meaningful formulation of their interrelationships.

ALLOMETRY OF WATER AND SOLIDS IN HUMAN FETUS

Although recent compilations of human fetal carcass analyses (such as Kelly *et al.*, '51) contain considerable numbers of specimens, many of these fetuses had to be eliminated for various reasons from the present study, and additional specimens were included from Widdowson and Spray ('51). The fetuses accepted for study here were all weighed intact and then dried in a low temperature oven. The difference between the original wet weight of the specimen and its dry weight equals total body water (in grams). The dry specimen must then have undergone fat extraction, so that fat-free solids in grams represent dry weight minus the weight of fat removed.

The sources of data included 15 male and 6 female fetuses from Fehling (1877), three males and three females from Camerer ('00a, '00b, '02), one male each from Brubacher (1890) and Sommerfeld ('00), and 11 males and 6 females from Widdowson and Spray ('51). Thirteen fetuses of unstated sex were used from Iob and Swanson ('34), and one from Langstein and Edelstein ('17).

The estimated menstrual age range of the specimens (chiefly from Kelly *et al.*, '51) was from 3.6 lunar months to term. Male body weights ranged from 36.5 to 4,375 g, female weights from 156.8 to 3,767 g, and for fetuses of unstated sex the range was from 59.4 to 2,915 g.

The allometric calculations were performed on an individual basis, by the method of least squares. Separate equations are presented for males, specimens of unstated sex, females, and for the total series. As shown in table 1, these equations are based on highly correlated logarithmic variables, and are therefore indicative of true allometric relationships.

TABLE 1

Allometry of water and fat-free solids in human fetuses

GROUP	N	EQUATION	σ_{est}	σ_k	$r_{\log S \cdot \log H_2O}$
(1) Males	30	$\log S = 1.251 \log H_2O - 1.509$	0.399	0.025	.9943
(2) Sex unstated	14	$\log S = 1.254 \log H_2O - 1.506$	0.159	0.029	.9969
(3) Females	15	$\log S = 1.275 \log H_2O - 1.581$	0.070	0.013	.9993
(4) Total series	59	$\log S = 1.255 \log H_2O - 1.518$	0.436	0.016	.9958

t test of significance of difference between male and female k coefficients:
$t = 0.53 \quad p > .05$.

Finney ('38) devised a statistical test, in the form of a critical ratio, which is a measure of the significance of the observed deviation of k from a value of $k = 1$. All of the fetal values of k shown in table 1 are very significantly greater than unity; p in all cases is less than 1 in 1,000 except in (2), where $p < .01$.

The males and specimens of unstated sex show practically identical equations: the females show higher absolute values of k and b. The agreement of the first two equations suggested that the female result might be a sampling deviation, and a test of significance was applied to the k ratios of the males and females (Simpson and Roe, '39). The difference was not significant, and consequently the equation for the total series is considered to be applicable to fetuses of either sex.

REFERENCE STANDARDS

Data at hand for the formulation of neonatal reference standards are not abundant. Widdowson and Spray ('51) analyzed three male specimens ranging in weight from 3,105 g to 4,375 g, and three females ranging from 3,050 to 3,767 g. These authors defined a single reference standard for both sexes, weighing 3,500 g. and containing 14% fat, 71.5% water, and 14.5% solids.

Our interpretation of these same raw data is that the male and female reference neonates should be alike in composition, but the female should be lighter in total body weight.

In arriving at mean reference weights for newborn American boys and girls, a grand mean for each sex was obtained from the separate means of 4 recent growth studies. The sources used were Vickers and Stuart ('43) for a group of Boston children, Bayley and Davis ('35) for a sample from Berkeley, California, Sontag and Reynolds ('45) for a series from central Ohio, and Boyd ('41) for a sample from Minnesota. The reference male neonatal weight is 3,550 g, and that of the female is 3,350. Both contain 14% of fat as recommended by Widdowson and Spray ('51).

The allometric equation for the total fetal series indicates that a fat-free body weighing 3,053 g should contain 2,496 g of water (70.3% of total body weight), and 557 g of solids (15.7%). These are accordingly the concentrations of water and solids in the male reference neonate.

For the female neonate, with a fat-free body of 2,881 g, the water content should be 2,362 g (70.5% of total body weight), and solids 519 g (15.5%).

Compared to the standard of Widdowson and Spray, the water contents of these reference neonates are perhaps 1% too low, and raise the possibility that dehydration of the fetal body before analysis (especially in the smaller specimens) is a systematic source of error in the equations. Hamilton ('36) had similar suspicions regarding his own equation, based on some of the fetuses used here (those of Iob and Swanson, '34). The present computations do verify, however, that the two sexes are probably alike in their composition of fat, total solids and water at birth.

The next step was to define a "reference woman" of age 25 years to compare with the reference man. Such a definition is somewhat suspect because of a scarcity of suitable data on the body composition of women. One possible reference body weight would be the mean of 8,516 abundantly fed young U. S. Army women from World War II (Randall and Munro, '49) at 59.8 kg, but in deference to civilian female sensibilities we have used the slightly lighter 58 kg, which is closer to the female mean "standard weight" for age 25, according to the Medico-Actuarial Standards of 1912. This choice is also consistent with the weight of the reference man, which is 70.6 kg, and which was similarly chosen from the 1912 tables (Keys and Brožek, '53).

From measurements of specific gravity in the living, Skerlj, Brožek and Hunt ('53) estimated that the mean fat content of 23 young women aged 18–30 years was 26.2% of body weight. Since the true mean standard weight of these women (relative to the Medico-Actuarial Standards) was 94.13%, the average young woman at the full standard weight is probably more adipose. A choice of 28% of fat for the reference woman seems more reasonable.

Since the two sexes are alike at birth in average composition, but the female is lighter in weight, it is of theoretical interest to construct the reference woman as though she, too, had essentially the same composition as the reference man, but with considerably more adipose tissue. Such a definition would make possible the use of existing adult male equations for body composition in the female as though she were a small, relatively adipose man. Somewhat analogous reasoning underlies the use of the same equations for both sexes in predicting total body fat from specific gravity or density.

In the computations which follow, the excess adiposity of the female will be interpreted as equivalent to the so-called "obesity tissue" gained or lost during moderate changes of weight in men (Keys, Anderson and Brožek, '55). As characterized by a combination of measurements of body density and body water, obesity tissue consists of 62% fat, 31% water, and 7% cell solids. The residual composition of the reference woman is that of the reference man: 14% fat, 61% water, and 25% non-fat solids. (Non-fat solids consist of 19% cell solids and 6% bone mineral.)

As previously defined, the total body weight of the reference woman is the sum of the obesity tissue and residual composition, or 58,000 g. Twenty-eight per cent of this aggregate is fat, or 16,240 g.

Let $Q = 1\%$ of the added obesity tissue

and $C = 1\%$ of the residual composition.

We solve the following two simultaneous equations to find Q and C:

$$\text{Weight of reference woman} = 58{,}000\text{ g} = 100Q + 100C$$

$$\text{Fat of reference woman} = 16{,}240\text{ g} = 62Q + 14C.$$

These equations yield $Q = 169.17$ g, and $C = 410.83$ g.

We then construct the reference woman by applying the appropriate multipliers:

CONSTITUENT	OBESITY TISSUE		RESIDUAL COMPOSITION		REFERENCE TOTAL (GRAMS)
Fat	$62Q$	+	$14C$	=	16,240
Water	$31Q$	+	$61C$	=	30,305
Solids	$7Q$	+	$25C$	=	11,455

In percentages of total body weight, the reference woman contains 28% fat, 19.7% non-fat solids, and 52.3% water. The agreement of this water content with averages in the literature for young women of representative average weights seems to support the preceding formulation: *i.e.*, Forbes ('52a) gives 51.9% as a mean for 11 women under 35 years of age. Edelman *et al.* ('52) give 51.5% for 19 women with a mean age of 23.8 years.

On a fat-free basis, the reference woman contains slightly more water than the reference man: *i.e.*, 72.6% as opposed to his 70.9%. These two values are used to define the mature hydration of male and female children in the calculations later in this paper.

FETAL ALLOMETRY OF WATER AND SOLIDS IN LOWER MAMMALS

In man, the data of Needham ('42), Hamilton ('36) and Forbes ('52a) indicate that total body water maintains an allometric relationship with total body weight or with total dry substance from the fetal period to the adult. But where water is related to *fat-free* solids, it is well to attempt new calculations. In a few lower mammals, for example, carcass analyses are plentiful enough so that separate allometric equations can be computed for the fetal period and for postnatal growth. This separation is not only a test of discontinuities at birth but may also suggest what kind of postnatal equation for solids and water might be applied to man, for whom no suitable carcass analyses are available.

Unfortunately, most of the fetal allometric calculations of Needham ('42) are based on studies where the specimens were dehydrated to determine dry weight, but were not subjected to fat extraction. A fetal equation so calculated will not be seriously in error if it is based on fairly immature fetuses, which in all mammals are practically fat-free, or on the whole fetal period in species where the newborn is virtually fat-free.

One such study was carried out in the pig. Wilkerson and Gortner ('32) performed carcass analyses of 1,552 embryonic and fetal pigs, ranging in weight in various age groups from 0.3 to 725 g. We consider these "solids" to be equivalent to our "fat-free solids." Needham ('42) calculated an allometric k coefficient, predicting solids from water for this series, and its value was 1.07.

In the rat, which contains only about 1% of fat at birth, Hamilton and Dewar ('38) performed analyses of 585 fetuses, ranging from the

14th day of gestation to term at 21 days. Water and dry substance in this instance showed an excellent allometric relationship, with the correlation between the logarithms of the two variables being +.9999. Predicting water from dry substance, these authors obtained a k of 0.875. The reciprocal of this coefficient, which is very nearly correct when the correlation is so high, is the prediction of solids from water. By this transformation, $k = 1.14$.

Our human fetal k coefficients were considerably higher. Relative to man's prenatal accumulation of body water, his "solidification" is striking. This trend is doubtless related to the consistently low water content and abundance of bone in the human fat-free body. This abundance of bone, in turn, probably accounts for the comparatively high concentrations of calcium, phosphorus, and sodium in the human fat-free body (Spray and Widdowson, '50).

POSTNATAL GROWTH OF BODY CONSTITUENTS

For comparison with the fetal coefficients for the rat and pig, and in order to explore more fully the postnatal allometry of water and solids in the fat-free mammalian body, data were taken from a recent synthesis of postnatal growth trends by Spray and Widdowson ('50). The carcass analyses most fully described in their paper are for the rat (black and white Hooded strain), pig (hybrids of Wessex and Large White in varying genetic proportions), and the rabbit and cat.

For two of these species (rat and rabbit), the series were large enough to permit separate studies of males and females. In both species, the sexes at birth were similar in mean fat, water and total solids, but the females were slightly lighter in weight. The human reference standards described previously were constructed in a similar manner.

First to be considered in the postnatal growth of these lower mammals is the fat content of the body. In all of the species studied, fat rapidly accumulates during the suckling period. After the end of weaning, the rat shows a temporary slackening in this rate of increase, but the other species show a true loss of fat relative to total body weight. This relative loss is reversed just before or during adolescence, and a relative accumulation sets in. The rat is peculiar in losing fat late in adolescence: the other species continue to show some increases. In the rat and rabbit, where the two sexes were studied separately, the female body does not contain more fat than that of the male until after puberty.

By comparison with most other mammals, man is unusually adipose at birth, but he, too, fattens considerably during the suckling period. Stuart and Sobel ('46) have measured the thickness of the medial and lateral layers of skin and subcutaneous tissue in the calf of the leg from radiographs of children followed serially for a number of years. These thicknesses attain an early maximum at 9 months of age which seems to correspond to the maxima of total body fat seen at weaning in the pig, rabbit and cat. After 9 months of age, these adipose layers become thinner at a decreasing rate until after the age of three years, remain about constant from 5½ to 11, and thicken again thereafter.

It is risky, however, to estimate the total body fat content of children from such measurements—particularly in the calf of the leg. As Reynolds ('52) has demonstrated, the subcutaneous layer undergoes considerable changes in distribution prior to adolescence. In general, these changes are in the direction of a considerable relative loss of thickness on the distal segments of the limbs, smaller losses on the proximal segments, and accumulation on the trunk. This redistribution prevents the reconstruction of a clear picture of trends in total body fat from any localized radiographic measurements of the subcutaneous layer in man.

In addition, if the subcutaneous layer maintains a constant thickness in a limb which is growing in girth, the percentage of adipose tissue in this region must be decreasing.

In a study now being prepared for publication, Mr. Paul T. Baker, Mrs. Tulika Sen, and one of us (Hunt) have been calculating idealized areas of cross-section of the brachium from measurements of radiographic shadows of children and young adults. The tissues measured have included marrow cavity, compact bone, muscle and adipose tissue at a point midway from acromion to olecranon. The age range of the individuals studied was from 6 years to young adults.

In boys, the precentage of adipose tissue at mid-brachium decreases constantly during this age span. In girls, the decrease ends at about 12 years, and in adolescence a slight increase occurs. The steady decline of adiposity in the male arm is unusual compared to total body fat in other known mammals. The trend in girls, however, resembles those of the pig and rabbit, whose total body fat shows relative decreases before adolescence, and slight increases thereafter. There is no certainty however, that the adipose trends in the human brachium really correspond with those of total body fat.

As early as one year of age, girls tend to show more thickness of the subcutaneous layers of the leg than do boys (Stuart and Sobel, '46). The female rat and rabbit, however, do not show a sex difference in total body fat until puberty.

In turning from fat to water and solids, the data of Spray and Widdowson ('50) portray the postnatal relative decrease of water in the fat-free body of several lower mammals. In the rat and rabbit, both species reach puberty at about the middle of their postnatal span of growth, and mature hydration soon afterward. We have calculated that at mature hydration, the rat is at about 75% of its adult weight, and the rabbit at 85%. The pig has a very early puberty, but like the other species, reaches mature hydration about halfway through its postnatal growth span. Its weight at mature hydration is about 75% of the adult value. The cat, however, is unusual in attaining mature hydration not long after weaning, and puberty near the end of its growth. At mature hydration, this animal is at only 60% of its adult weight.

If man shows any resemblance to these species, we should expect him to attain mature hydration at the latest toward the middle of his postnatal time span of growth, and at a weight of between 60 and 85% of the adult value.

There remains the question of whether water and solids maintain strict allometry in their postnatal growth in lower mammals, at a time when fat undergoes quite different rates of accumulation or relative loss from one species to another. To examine this question, a series of allometric equations was computed by the method of least squares, using data on water and solids from the tables and charts of Spray and Widdowson ('50). Only ages below the probable time of mature hydration were included.

Since means of several age samples were used for each species instead of individual specimens, the correlations between log solids and log water are higher than they would be otherwise, and individual standard errors of estimate of solids from water cannot properly be given. The weights of both constituents are in grams.

Table 2 shows that all species exhibit a postnatal allometry of water and solids up to the age of mature hydration, despite their different relative accumulations and losses of fat. These findings are highly suggestive of a comparable allometric pattern during human postnatal growth.

In the rat and rabbit, where separate curves were calculated for males and females, the females showed higher absolute values of the *k* and *b* coefficients. Especially in the rat, the female reaches mature hydration younger than the male. A hint of such a sex difference was also found in the human fetal equations for males and females, but was dismissed from further consideration because the divergence was far from approaching statistical significance.

In the pig and rat, where comparisons are possible between prenatal and postnatal values of *k*, the postnatal coefficients are higher. The increase in the pig is from 1.07 to 1.10, and in the rat, from 1.14 to 1.24.

TABLE 2

Postnatal allometry of water and fat-free solids to time of mature hydration in lower mammals

SPECIES	SEX	N	AGE RANGE (DAYS)	EQUATION	$r_{\log S \cdot \log H_2O}$
(5) Rat	Male	76	0–120	$\log S = 1.24 \log H_2O - 1.00$	.9994
(6) Rat	Female	73	0– 90	$\log S = 1.25 \log H_2O - 0.96$	.9998
(7) Rabbit	Male	22	0–250	$\log S = 1.14 \log H_2O - 0.94$	.9933
(8) Rabbit	Female	21	0–250	$\log S = 1.18 \log H_2O - 1.05$	.9967
(9) Cat	Both	18	0–126	$\log S = 1.18 \log H_2O - 1.02$	.9990
(10) Pig	Both	37	0–251	$\log S = 1.10 \log H_2O - 1.03$	.9995

After birth in these species, then, the fat-free body "solidifies" more rapidly than prenatally, relative to the accumulation of water. Especially in the rat, the use of a fetal equation for predicting solids and fat in older juvenile animals would result in systematic underestimation of solids, and therefore a corresponding overestimation of fat. It would also yield too late an age of mature hydration.

If man, too, "solidifies" more rapidly after birth than prenatally, the same errors should result from using the fetal human equation for predicting solids, fat, and the time of mature hydration in children. But this fetal equation is very useful in indicating a likely *maximum* age of mature hydration, beyond which adult hydrometric equations can be used with considerable confidence.

Furthermore, if this maximum age agrees well with the established ages of mature hydration in some of the lower forms, this finding might indicate that at the most, the postnatal acceleration of "solidification" is small in man, as in the pig, rather than large as in the rat. Finally, the smaller the postnatal acceleration of *k* in man, the more accurately the fetal equation will delineate the postnatal trends of fat and solids in children.

MATURE HYDRATION IN MAN

In calculating the body size and probable timing of mature hydration during human growth, the equation for the total human fetal series was used. The ratios of water and solids at which mature hydration is reached in boys and girls were arrived at by successive approximations.

Mature hydration in boys, where water is 70.9% of the fat-free body weight, is reached when the body contains 27,000 g of water, so that the fat-free weight is 38,067 g. In girls, mature hydration at 72.6% of water in the fat-free body is attained when water reaches 19,500 g, so that the fat-free weight is 26,845 g.

For boys, if we assume that this fat-free weight is 80% of total body weight, the intact individual then weighs 47.6 kg. If the corresponding fat-free weight of the female is 75% of total body weight, the intact body at the onset of mature hydration weighs 35.8 kg.

In males, body weight at the onset of mature hydration is then 67% of the weight of the reference man. The equivalent stage in girls is at 62% of the weight of the reference woman. In both sexes, these weights are in the lower portion of the range for lower mammals which was described previously (60–85%). This finding suggests that the postnatal allometric accumulation of solids in the human fat-free body proceeds at approximately the fetal rate or, at most, a slight acceleration occurs as in the pig.

In boys and girls, when the body weights at the onset of mature hydration are translated into age equivalents, using mean weights for age published by Sontag and Reynolds ('45), it is estimated that boys reach mature hydration at almost 14 years of age, and girls at about 10½ years.

These calculated ages of mature hydration in man occur at about the middle of the postnatal time span of growth, as in the pig, rat and rabbit. The precocity of the human female seems to be part of a pattern of rapid maturation which affects most of the body except for the eruption of the deciduous teeth (Meredith, '46).

WATER, SOLIDS AND FAT IN PREADOLESCENT CHILDREN

Friis-Hansen *et al.* ('51) have published deuterium oxide and antipyrine determinations of total body water for 20 children from neonates to the age of 10.8 years. These children were patients at Children's Hospital, Boston, so that some question may arise as to their "normality" of body composition. Despite this doubt, the more numerous male sample of 16 individuals has been used to calculate age trends of water, solids and fat, where each constituent is expressed as a percentage of total body weight. Water in each individual was the mean of the D_2O and antipyrine spaces. From this mean value, solids were calculated by the allometric equation for the total fetal series which was derived earlier.

Where age in years is represented by A, the least-squares regression of non-fat solids on age from birth to 10.8 years is expressed by the following equation:

$$\text{(11)} \qquad \%\ \text{Solids} = 0.43A + 16.16.$$

The initial, or neonatal value of solids in this equation, where $A = 0$, agrees fairly well with the reference neonatal male value of 15.7%. Through the preadolescent years, boys accumulate solids with great regularity. A less certain deduction is that this equation continues to apply during adolescence. If the precentage of solids in the reference man (25%) is substituted into this equation, we obtain a terminal age for progressive "solidification" of just under 21 years. Research on adolescents should determine whether solidification is regular from 10 to 21 years, or accelerates during the adolescent growth spurt and slows down afterwards.

The original data of Friis-Hansen *et al.* ('51) show that total body water rapidly declines relative to body weight up to the age of 9 months, and is far more stable in the later preadolescent years. The following equations express the age trends of water in boys:

$$\text{(12)} \qquad \text{(Birth to 9 mo old)}\ \%\ H_2O = 71.06 - 14.69A.$$

$$\text{(13)} \qquad \text{(1 year to 10.8 years)}\ \%\ H_2O = 59.52 - 0.42A.$$

The equations for water and solids for corresponding ages can easily be combined to produce equations expressing the hydration of the fat-free body as related to age.

$$\text{(14)} \qquad \text{(Birth to 9 mo old)}\ H_2O(\%\ \text{fat-free body}) = \frac{7106 - 1469A}{87.22 - 14.26A}.$$

At later ages, with the cancellation of practically equivalent terms in the denominator, we arrive at the simple expression:

(15) (1 year to 10.8 years) H_2O(% fat-free body) $= 78.6 - 0.6A$.

The equations for fat content of the total body are readily obtainable if the equations for water and solids are combined, and then subtracted from 100%. By this method, we obtain one equation for fat up to 9 months of age, and another extending from one to 10.8 years.

(16) (Birth to 9 mo old) % Fat $= 12.78 + 14.26A$.

(17) (1 year to 10.8 years) % Fat $= 24.32 - 0.01A$.

These equations show that the value for fat in the newborn is 1.2% lower than that of the reference male neonate, probably because lengths were average in the 8 young infant males studied, but weights were a little low relative to the standards in Sontag and Reynolds ('45). Nevertheless, in this group, the fat content of the body almost doubled in the first 9 months of postnatal life. Up to 10.8 years, fat is essentially stable, while water slowly declines and solids accumulate at inversely corresponding rates.

This stability of total body fat in boys runs counter to the relative loss of adipose tissue at mid-brachium as shown from radiographs. The discrepancy would be even more marked if mature hydration is attained at any age younger than the one predicted from the fetal allometry of water and solids in man.

Although the preceding equation for water as a percent of the total body weight in older preadolescent boys indicates a slight decrease, it is based on a sample of only 8 individuals. A constant water content from one to 10 years is almost equally plausible, but if mature hydration were reached during this interval, from that time onward the curve for solids would have the same slope as the curve for water. Correspondingly, fat would either remain constant, or else increase.

From these considerations, we conclude that the loss of fat in the brachium in boys from 6 years onward is produced by a *redistribution* of the subcutaneous layer rather than by a reduction in the total fat content of the organism.

This finding again emphasizes that radiographic shadows or skinfolds are very valuable *localized* indicators of adiposity in children, but it will probably be no simple matter to use them for the prediction of total body fat.

BODY COMPOSITION IN ADOLESCENCE

Since the ages of mature hydration were calculated from the fetal equation for children of both sexes, these estimates are apparently either correct, or else slightly overshoot the mark. Because these calculated ages are maxima, *hydrometric equations based on young adults can be used with confidence on adolescents.*

In boys, the regression equations on age of fat, solids and water suggest that adolescence involves a considerable transformation of body composition. The normative composition of a 10-year-old boy, as calculated from these equations, is about 24% fat, 55% water and 21% non-fat solids. The reference man is far less adipose and more "solid," with 14% fat, 61% water and 25% solids. The trends by which this transformation is achieved remain to be worked out in the future.

Although data on body composition are scarce for girls, a notable resemblance exists between the normative 10-year-old boy, as described above, and the reference woman (28% fat, 52.3% water and 19.7% solids). It can be expected that future studies of girls will show that at the time of mature hydration, the female is at about the mature level of total body fat as well. If this suggestion is true, the well-known adolescent changes in female adiposity will prove to be far more a matter of redistribution—especially of the subcutaneous layer—than of absolute increases in the precentage of fat in the body as a whole.

DISCUSSION

In this paper, the hydrometric method has been deliberately overextended. From the evidence, it appears that man shows several typically mammalian growth trends in his body composition. Since direct confirmation of these trends by carcass analyses of children is unlikely in the near future, the substantiation or revision of the present findings will probably have to be done in the living.

Of particular importance is a better established value of k for solids predicted from water in preadolescent children. From such an improvement, better estimations of the age of mature hydration and the growth of fat and solids can be derived.

An approach to the calculation of body fat from body density in children could proceed in a direction parallel to the present study. Boyd ('33) has published a compilation of specific gravities of dead fetuses and living children. Since the fetal data were based on specimens which had never breathed, these determinations are relatively comparable with modern studies of adults, where accurate individual corrections are made for the presence of air in the lungs (Brožek, Henschel, and Keys, '49). For living children and adolescents, however, modern determinations of density are very much to be desired, and no integration of hydrometry and densitometry at these ages will be possible until such data become available.

SUMMARY

A method is presented by which developmental trends in the body composition of children and young women can be effectively described. It is a beginning in the formulation of a system of calculating body composition from body water, density, radiography and skinfolds, comparable to the methods now used for young men (Keys and Brožek, '53).

Allometric equations are calculated between the solid and water content of the fat-free body in human fetuses and neonates, using carcass analyses from the literature. The question of sex differences is explored, and an overall equation finally computed on 59 specimens. This equation is also used to define "reference neonates" of both sexes, containing representative amounts of fat, water and fat-free solids. By considering a typical young American woman as a small, relatively adipose man, it is possible to define a "reference woman" comparable to the "reference man" of Keys and Brožek ('53). This female reference standard has a water content which agrees closely with data in the literature on the hydration of young women.

Since few carcass analyses of human children are known, an attempt was made to work out the postnatal allometry of water and solids in man, by analogy with data on lower mammals. In the pig, and to a much greater degree in the rat, the "solidification" of the fat-free body relative to its accumulation of water proceeds more rapidly postnatally than *in utero*. This postnatal solidification continues allometrically until the mature concentrations of water and solids are attained in the fat-free body. From this time until the animal is fully grown, water and non-fat solids then maintain a constant ratio.

Various calculations for man suggest that the postnatal allometry of water and solids in children continues at the fetal rate, or else with only a slight acceleration as in the pig. If no acceleration takes place, it is possible to estimate the time of mature hydration in man from the

fetal equation without error. If acceleration occurs, however, the fetal equation overestimates the time of mature hydration.

Using the human fetal equation, it was estimated that mature hydration in children is reached at 10½ years in girls and at nearly 14 years in boys. This indicates the possibility of using young adult formulae for computing the fat-free body weight from water whenever hydrometric studies are contemplated on adolescents.

The trends of postnatal body composition in children, as indicated from the fetal equation, are in some respects similar to those of other mammals, and in others unique. At birth, man is a notably adipose organism. *In utero*, he has accumulated non-fat solids (especially bone) rapidly relative to his gain of water, so that his neonatal fat-free body contains less water than that of most lower mammals. He fattens greatly during the suckling period, as do other species.

From weaning to pubescence, man loses little or no fat: the rabbit, cat and pig show quite definite peaks of adiposity at weaning and temporary losses relative to total body weight thereafter. During the preadolescent years, human children undergo gradual relative decreases of total body water and corresponding increases of solids.

In the rabbit and rat, where sex differences have been adequately measured, the female becomes more adipose than the male only after puberty, while in man this difference seems to appear much earlier.

In the rabbit and pig, fat accumulates considerably throughout adolescence, but in the rat this fattening occurs in the earlier part of adolescence, and the animals become less adipose as growth comes to an end. In adolescent girls, the composition of the body changes only slightly, as in the cat, and redistribution rather than accumulation of adipose tissue is suggested by the data. Boys, however, lose much fat and gain considerably in water and solids. This adolescent male pattern is unusual compared with the trends in other known mammals.

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BOOK REVIEWS

Weight Control: A collection of papers presented at the Weight Control Symposium. Edited by ERCEL S. EPPRIGHT, PEARL SWANSON and CARRORLD A. IVERSON. viii + 244 pp. The Iowa State College Press, Ames, Iowa, 1955. $2.50.

It is essential for biological survival that every animal should carry about some reserves of food against an emergency. The chemical form is varied. In man the carbohydrate reserve is trivial—at most 500 gm and usually much less. There is a considerable uncertainty as to how much of the protein in the body constitutes a true reserve, but a moiety of the body's protein is undoubtedly labile and this constitutes a true reserve. However, the principal store of food is in the form of fat and the greater part of body fat can be utilized to maintain life during a period of prolonged partial starvation. There is, however, no certainty as to how large this store should be in normal health. It certainly varies a great deal in different individuals. There are now a number of ways of measuring the fat content of a man: of these, the most reliable depends on the fact that fat floats and, if the density of a man is determined by underwater weighing, then the proportion of fat in the body can be calculated. Keys reported that the mean fat content of the people of Minnesota was as follows: young men 14%, young women 25%, middle-aged men 26%, middle aged women 38% of body weight. There are, of course, wide variations about this mean. There is now an accumulation of evidence that an excess of fat is associated with an increased liability to a variety of diseases and a relatively low life expectancy. Excess fat is a biological hazard. There is, however, no indication of what the ideal size of the fat store should be. The size of the actual stores is dependent on the balance between the food eaten and the energy expended in everyday life. Men, of course, must obey the First Law of Thermodynamics, and so a gain in weight must result from a positive energy balance. Normally the appetite mechanism preserves an exact balance and appetite is a good example of a fine "homeostatic mechanism." We know, however, very little about the components of the mechanism. They are in part chemical, in part nervous, and they are also subject to psychological factors. Each of these can be disturbed. There is now good evidence that obesity can arise from psychological, chemical and neurological trauma and, as Mayer points out clearly in the Symposium, there are several different types of obesity with different etiologies. These have been most clearly defined in the mouse, which is an excellent subject for experimental study, but the human analogues of the various types of mouse obesity probably exist.

In human obesity, attempts at control by reduction in the diet have been for the most part very disappointing. Most fat people find it very difficult to cut down their food intake and, in many, the attempt is associated with real discomfort. Many obese persons do not indeed eat in excess of the generally acepted physiological standards. Their obesity results not so much from over-eating but from under-exercising. Swanson, after reporting that many women appeared to be fat on a daily intake of 1750 Calories or even less, concluded that their energy expenditure must be very low. Their life must be mainly "sitting around." It is only just beginning to be appreciated that one of the results of "progress" in a civilization is that *Homo sapiens* becomes converted into *Homo sedentarius*. *Homo sedentarius* is far from being a "normal" man. In particular his or her appetite fails to establish a normal control of body fat stores. Again the nature of this failure is not fully understood. But the failure presents one of the greatest challenges to human biology.

The participants in the Iowa colloquium discussed these problems clearly and the account here presented makes a most readable book, which can be recommended to biologists with no special knowledge of the subject. The committee responsible for organizing the colloquium and publishing the proceedings deserves credit for their judgment in selection of speakers. The Iowa State College Press have made an excellent job of the production of the volume.

R. PASSMORE

University of Edinburgh,
Edinburgh, Scotland.

Methods for Evaluation of Nutritional Adequacy and Status. Edited by HARRY SPECTOR, MARTIN S. PETERSON, AND T. E. FRIEDEMAN. vii + 313 pp. National Academy of Sciences—National Research Council, Washington, 1954. (no price).

Since nutritional status is an ecologic concept, the subject of nutrition involves persons working in the biological and in social sciences. It is not surprising, therefore, to find in this symposium a wide array of papers (ranging from essential nutrients, through body composition, to the statistical evaluation of population surveys), presented by a wide variety of investigators and approached from the point of view of diverse fields. In reading the 313 pages, the importance of this type of interchange of information becomes readily apparent.

The approach of the symposium is, in another fashion, justifiably limited. The major interest and concern of the Armed Forces is the young, healthy adult male. The emphasis is then on the problems of methodology in the study of nutrition from their point of view.

Nutrition classically involved the study of nutrients so essential to the diet that their absence induced death or specific disease. Today the approach has matured, and the concept of nutritional status has come to involve also the effect of nutrients on the composition of the organism and the effect of this composition on function. The subject of essential nutrients is well covered in this symposium and includes classical and new discussions on proteins, vitamins and minerals. The topic of physical composition is also covered and will be discussed later in this review.

Function, in the final analysis, determines nutritional adequacy or inadequacy, and yet disregarding frank deficiency states, is a newcomer in the field of nutritional symposia. "Adequacy" unfortunately involves complex matters as productivity, be it economic, intellectual, or procreative, and encompasses even the moral behavior of an individual or a society over a brief time or generations. The Army has less involved interests. Their concern relates to the effect of food on morale, to the ability to perform tasks, to withstand severe stress and to recover promptly from physical or psychologic trauma. The appearance in this symposium of material relating to function should stimulate more workers in the field to include this most fundamental aspect of nutritional adequacy in future studies.

It was in the discussion of body composition that an element of stagnation appeared. The determination of body composition *in vivo*, classically, as is discussed fully in the symposium, assumes constancy of the lean body mass in one form or another. Such constancy is physiologically unlikely even in health. Homeostasis, or the constancy of the *milieu intérieur*, is a goal that the organism attempts to attain by varying its physiologic processes within the parameters tolerated by survival. The resultant inconstancy should be recognized (for instance: Adolph, "Physiological Regulations"), and it is the inconstancy rather than the constancy that may be meaningful. The assumption of constants, or reference standards, may mask or leave neglected areas equally as important as the relative fatness or leanness of any individual. In growth the concepts of change are most impressive, and the assumption of a constant composition or even density of the lean body mass may have to be discarded. It is unlikely even in the adult that such constancy exists or should be hoped or looked for. It seems to this reviewer that the description of the parameters of body composition and their interactions in normal men, which are described briefly in this symposium, may lead to more important methodology than the more emphasized discussion of the relative merits of a standard or reference body or the assumption of constancy of any single phase of composition or function.

All in all, the symposium is stimulating and readable. It leads one to hope that eventually we will know whether Jack Spratt's dietary digressions were, in the long run, worthwhile. The Armed Forces should be congratulated for stimulating and supporting this form of endeavor.

RALPH J. WEDGWOOD

University Hospitals,
Cleveland, Ohio

Fluid Therapy. By JAMES D. HARDY. 255 pp. Lea and Febiger, Philadelphia, 1954. $5.50.

The Body Fluids. By J. RUSSELL ELKINTON AND T. S. DANOWSKI. vi + 626 pp. Williams and Wilkins, Baltimore, 1955. $10.00.

Connective Tissues. Edited by CHARLES RAGAN. 222 pp. Josiah Macy, Jr. Foundation, New York, 1954. $4.25.

Clinical Disorder of Hydration and Acid-Base Equilibrium. By LOUIS G. WELT. viii + 262 pp. Little, Brown and Co., Boston, 1955. $6.00.

While the interest in the physiological role of water in the animal body began to develop more than 100 years ago, its significance for medicine has been made clear only a few decades ago. In the last quarter century great progress has been made in this field, with every sector of clinical medicine benefiting from the increased knowledge concerning the role of the changes in body hydration in different disease states. Measures aiming to correct the disturbances of water and electrolyte equilibria were developed and "fluid therapy" is today an important tool in every medical or surgical clinic. However, the study of changes of the water content of the body is important also for the biology of the "normal" man.

The books listed above present a good picture of the current status of this field. While the basic physiology is considered, the emphasis is placed on practical therapeutics. *Fluid Therapy* gives the answers to many practical problems in the management of clinical alterations of hydration and electrolyte balance, with special reference to surgical patients. Elkinton and Danowski provide a more comprehensive treatise. Diagnostic and research methods are discussed and the practical procedures of therapy are presented in detail. Welt's volume is a valuable and up to date discussion of the clinical manifestations produced by altered hydration of the human body and of their treatment. The first part, about a third of the book, presents the basic physiologic and physicochemical concepts.

The book on *Connective Tissue* is of a different character than the other 3 volumes and, in keeping with the pattern of the Josiah Macy conferences, it presents a discussion of selected topics. The section on interstitial water and connective tissue by Gaudino will be of interest to those engaged in studies of water metabolism and contains valuable information derived from the author's work.

While the publications dealing with body fluids are apt to stress the clinical (diagnostic and therapeutic) applications, it should be noted that there are several fields of human biology, including the sciences of human nutrition and exercise, studies of growth and development, and gerontology, in which the determination of body water and the analysis of its distribution in the different compartments yields important information on body composition.

FRANCISCO GRANDE

University of Minnesota,
Minneapolis, Minnesota

Progress in the physiology of farm animals. Edited by JOHN HAMMOND. Vol. I, vii + 392 + xv pp. Vol. II, 395-740 + xv pp. Butterworths, London, 1954, 1955. 45 s. per volume.

During the past quarter century a large amount of research was done on the nutrition, ecology, growth, behavior (with special reference to grazing and mating), locomotion and reproduction of farm animals.

It is the purpose of the present two volumes, shortly to be followed by the final tome, to provide a review and synthesis of this newer knowledge. Individual chapters represent authoritative summaries of the "bulges" along the advancing front of scientific animal husbandry. Availability of well-defined quantitative criteria of "fitness," together with some other factors (including the opportunity for rigorously controlled longitudinal studies), brings out the importance of work in this area for the human biologist, even though the presence of species differences can not be disregarded any more freely than when the results of studies on small laboratory animals are considered.

In the more strictly experimental biological sciences—in physiology, biochemistry, science of nutrition, experimental pathology—the interaction between animal and human studies is a good deal more intensive than in the studies of growth and development, of body form and composition. It is the contributions in this field that will be considered in greater detail here.

Live-weight growth was treated by R. W. Pomeroy (pp. 395-429). Among factors affecting this variable the author considered the "plane of nutrition," vitamins, sex (genetic differences), hormones, and antibiotics. Surprisingly enough, "very little work has been carried out on the factors that influence life-time performance" (p. 401). Thus the information, badly needed in human biology, on the effects of the rates of growth on longevity is inadequate. However, the studies of Hannson *et al.* (1953) confirm C. M. McCay's earlier work on laboratory animals and indicate that the average length of life of heifers reared on a low plane of nutrition was 95 months compared with 75 months for animals reared on a high plane of nutrition.

Nowhere has it been realized more clearly than in animal husbandry that live weight is an inadequate criterion of "growth" and that it must be supplemented by data on carcass composition. H. Pálsson's long chapter on Conformation and Body Composition (pp. 430-542) will be read with profit and interest by physical anthropologists, human anatomists, and pediatricians concerned with problems of growth. The fact, brought out earlier (p. 214), that external similarities between the fat-storing hump of the camel and the purely muscular thickening in the cervico-thoracic region of the Nilotic (Sanga) cattle are grossly deceptive, should make us pause and evaluate more rigorously the validity of somatoscopic ratings in man.

Methodologically, the single most important advancement in the animal studies was J. Hammond's complete-dissection method (1932) in which the total body is separated anatomically into its component organs and tissues and the weight of each is recorded, together with data on individual bones of the skeleton. The components are expressed as percentages of total weight or, preferably, are compared with a standard organ or part (such as cannon bones or brain-plus-eyes). Hammond and his students and coworkers (McMeekan, Pálsson, Wallace, etc.) used this technique for a systematic analysis of developmental changes in different anatomical regions and in the major organs and tissues of the body. These changes are the basis for the alterations in the conformation of the animal from birth to maturity. Different tissues attain their maximum growth rate during postnatal period in a definite order (central nervous system, bone, muscle, fat) and body fat is accumulated with age in different depots at different rates.

Of basic importance for the assessment of the concept of a definite, "genetically determined" body build is the fact that the animal's form and body proportions can be controlled within fairly wide limits by changing the plane of nutrition of the growing animal. Thus "different planes of nutrition not only produce animals of greatly different weights at the same age, but also of vastly different conformation and composition" (p. 479). This matter appears so important to the reviewer that he feels compelled to supplement the citation by a concrete example: "In general, cattle reared on a low plane of nutrition retain the juvenile form; they are leggy, narrow and shallow in the body, especially in the hind quarters, with long, large heads, as compared with animals of the same breed, even identical twins, which are reared on a high plane of nutrition. As in sheep, limited nutritive supply largely inhibits the normal development of secondary sexual characters" (p. 498). The principal tissues as well as the various internal organs are affected to different degree by the restriction of nutritive supply, with gradients of increasing retarding effects proportional to the postnatal growth intensity of the tissues.

The only serious limitation of Pálsson's presentation is the omission of reference to the recent advances in the study of body composition in living man and in intact animals, based on the determination of body volume (and body density), partitioning of the total body water, and measurements of optical bone density from roentgenograms serving as an index of mineralization. A closer contact between the students of the structure of farm animals and of man would be advantageous to both.

University of Minnesota,
Minneapolis, Minnesota

JOSEF BROŽEK

The Regulation of Hunger and Appetite. Edited by **FRANKLIN HOLLANDER.** 114 pp. Annals of the New York Academy of Sciences, Vol. 63, Art. 1, New York, 1955. $3.00.

This publication represents the proceedings of a conference convened by the New York Academy of Sciences in November 1954. The 14 papers are divided into three groups (Regulatory Mechanisms, Disorders of Regulation, and Clinical Aspects) and give a fair representation of the points of view and areas of interest of American scientists engaged in this field of research.

It is quickly apparent that agreement on the definition of the terms "hunger" and "appetite," one of the stated purposes of the conference, was not achieved. Thus Quigley adheres to the classical definitions of Cannon and Carlson, designating hunger as unpleasant and appetite as pleasant sensations. Mayer does not attempt rigid definition but subscribes to the view that hunger and appetite are sensations and feelings whereas the phenomena which the scientist is able to measure are such things as food intake and body weight. Brobeck dispenses with the problem by stating that he uses the terms "'appetite' and 'satiety' in a purely behavioral sense, without prejudice as to their subjective or psychological nature." Janowitz and Hollander state that appetite, defined as the desire to eat, can be measured operationally in terms of the amount of food eaten, thus assuming that appetite is the *sole* determinant of eating behavior. Grossman distinguishes between bodily states, behavioral states and psychic states, and further divides behavioral states into learned and unlearned and psychic states into sensation and affect. Thus he speaks of the bodily state of depletion giving rise to unlearned behavioral activity of feeding reflexes and the sensation of hunger. With the establishment of conditioning hunger sensations evoke the affective state of appetite, desire for food, which is reflected behaviorally in learned appetitive acts. While the problems of definition were not resolved by the conference, there was ample recognition of the necessity for distinguishing between and integrating biochemical events, motor acts and psychic states.

Perhaps the greatest contribution in recent years to the understanding of regulation of food intake is the discovery of the effect of discrete lesions of the hypothalamus. This topic is admirably reviewed by Brobeck who has been a leading worker in this field. His recent discovery of a hypothalamic area, destruction of which causes aphagia, will undoubtedly give further impetus to this active field of investigation.

This collection of papers is an important document for all who are interested in the subject. It offers the viewpoints of physiologists, nutritionists, psychiatrists, and psychologists.

Morton I. Grossman

V. A. Hospital, Los Angeles, California

Roberts' Nutrition Work with Children. By Ethel Austin Martin. xvi + 527 pp. University of Chicago Press, 1954. $7.50.

This is the third edition of a classic book on child nutrition by Lydia J. Roberts, first published in 1927. The book was completely rewritten but its aim remains the same, namely, to present principles and practices relevant for attaining better nutrition in children. Readers of this journal will be more interested in the first part of the book, concerned with the basic understanding of the problems. The second part, valuable in its own right, is devoted to educational procedures.

Clinical, chemical, and dietary methods and the assessment of physical growth are considered, and the extent to which each method alone or in combination with the other measures may be used for characterizing nutritional status are discussed. Some 70 pages are devoted to the problems of growth, including the general character of physical growth, factors which affect growth patterns (sex, size, socio-economic status, secular trends, geographic location, race and nationality, defect and disease, season of the year), measures of physical maturity (especially the comparison of roentgenograms of the hand and the wrist with the Greulich-Pyle standards), and a variety of growth standards (Baldwin-Wood age-height-weight tables, the Wetzel grid, Stuart-Meredith growth norms, and Meredith physical growth record). The review of American growth studies, including important current longitudinal investigations, will be appreciated by many.

The most frequent reasons why a child fails to become well nourished and the possible effects of malnutrition on physical growth, dental caries, the course of disease, the nervous system, mental ability, and emotional stability are examined. A large amount of space is devoted to constructive programs designed to help a child to become and remain well nourished. Among the topics discussed are effective nutrition teaching, the school lunch, and the nutritional teaching aids for school and community programs. Chapter VIII contains a valuable description of activities of national and international organizations dealing with nutrition research and educational programs.

The book is well written and will continue to be useful as a text for the student of nutrition, as a guide in practical nutrition programs, and as a reference book. The bibliographies appended to individual chapters will be welcome by those who are seeking more detailed information on a specific subject.

José Méndez

Instituto de Nutrición de Centro America y Panama,
Guatemala, C. A.

Tea: A symposium on the pharmacology and the physiologic and psychologic effects of tea. Edited by Henry J. Klaunberg. 64 pp. The Biological Sciences Foundation, Ltd., Washington, D. C., 1955.

The "proceedings" are thin when measured in reference either to the number of pages or to the added knowledge on the subject. The two papers that report new experimental results are reprints of articles published elsewhere. Nevertheless, both a lover of the brew and students of the many facets of the "biology of tea" will peruse the 8 reports with interest and some profit.

A tea infusion has no practically relevant caloric value, contains no sodium and, as S. O. Waife tells us in the introduction, there is scarcely a therapeutic diet in which tea could not be incorporated with impunity. While jam, sugar, milk and pastries can increase the caloric value and enlarge the range of taste-bud stimuli, it is precisely because of its blandness and nutritional innocence that tea is so useful in medicine.

Tea is a versatile beverage, with a delicate and varied aroma, a "social drink" in the best sense of the word, with a tendency to increase alertness, to relieve fatigue, and to produce a sensation of comfort and cheerfulness without being followed by depression.

While an industrious organic chemist can detect in tea traces of a variety of substances, the methylated xanthines, including caffeine, and the tea-tanins are the most important constituents, even though the volatile oils perhaps should not be neglected. The pharmacological effects of the modest amount of caffeine on the cerebral cortex are importantly reinforced and accentuated by social customs and pleasant associations.

Several authors stress the necessity to study the effects of tea infusion as such, not in terms of the chemical components. It was noted that tea tannins are not identical with tannic acid and that in a properly brewed tea the disturbing effects of caffeine alone and of tannin alone are not present. Tea has a moderate diuretic effect, increases gastric tone and motility, and shortens gastric emptying time, with iced tea having a more pronounced effect in this regard than hot tea. A shortening of simple and complex reaction time was noted in both immediate tests and delayed tests. The immediate effect, clearly, can not be ascribed to the pharmacological action of caffeine and points to a neglected area of study that may, eventually, substantially increase our understanding of "mental fatigue."

JOSEF BROŽEK

University of Minnesota,
Minneapolis, Minnesota

Third International Congress of Nutrition. 486 pp. Stichting tot Wetenschappelijke Voorlichting op Voedingsgebied, The Hague, 1954. (no price).

What Graham Lusk first called the science of nutrition is relatively a late comer. Nevertheless its achievements during the life span of one generation have been remarkable. As an entity, the science of nutrition is a different thing from the classical disciplines taught in universities, *e.g.* physiology, chemistry or physics. It is not limited by the use of one set of technics (as biochemistry) or a scale of structures (as bacteriology). It covers the organic chemistry of nutrients, enzyme chemistry of vitamin function, biochemistry of interconversion of metabolites, physiology of digestion and of regulations of energy exchange and of metabolism, behavior in relation to food, social and economic aspects of food distribution, production and utilization, legal protection of consumers, and a whole branch of medicine dealing with the deficiency diseases and the part of nutrition in the etiology of degenerative diseases.

All these aspects were touched upon at the third International Congres of Nutrition, held in Amsterdam, September 13th to 17th, 1954. The proceedings of the Congress appeared first in the form of separate articles in the Dutch nutrition journal *Voeding* and have recently been collected in book form. This reviewer participated in the Congress and would like to mention that he never attended a scientific meeting more excellently organized. All participants are in the debt of Professors B. C. P. Jansen, M. van Eekelen, and M. J. L. Dols.

The Congress was essentially centered around three topics: obesity, protein malnutrition, and food additives. The choice of these topics is symptomatic. Protein malnutrition in children is the great nutritional scourge of poor areas and is the greatest preoccupation of the Food and Agriculture Organization and of the Nutrition Section of WHO. At the other end of the scale in the Western world, abundance of food and lack of need for physical work have provided an ideal environment for the development of obesity. Modern technology entails its own risks, not the least of which is the possibility that some of the substances used as antioxidants, preservatives, etc. may be toxic and that some of the pesticides (which are, of course, known to be toxic for at least some living species) may not be completely eliminated.

In addition to the three symposium-like groups of papers, there were presentations on unrelated topics, a number of which were of great interest. Space does not permit to cite them all, but the scope of the Congress is exemplified by three of the outstanding papers dealing with: the psychological aspects of nutrition (with special reference to experimental psychodietetics), nutrition as a factor against addiction, and aspects of nutrition research of special interest to FAO.

The book is attractively printed, easy to read, and has good illustrations.

JEAN MAYER

Harvard School of Public Health
Boston, Massachusetts

BOOK NOTICES

ANDROGENS. By Ralph I. Dorfman and Reginald A. Shipley. xii + 590 pp. John Wiley, New York, 1956. $13.50. The androgenic hormones play an important role in the development of male secondary sex characteristics and the male accessory organs of reproduction as well as in the production of male gametes. In both sexes androgenic substances influence libido and protein anabolism. A prodigious amount of information is summarized in reference to the biochemistry, physiology (incl. growth and behavior) and clinical significance of androgens for the benefit of medical and graduate students, clinicians and research workers.

BIOCHEMISTRY AND THE CENTRAL NERVOUS SYSTEM. By Henry McIlwain. vii + 272 pp. Little, Brown and Co., Boston, 1955. $9.50. A systematic presentation of biochemical studies of the brain, developed from research and from teaching in physiology and in psychological medicine at the University of London. Includes consideration of glutamic acid and metal phenomena, and of vitamins (thiamine, nicotinic acid, B_6, B_{12}, pantothenate, riboflavin) the deficiency of which most prominently affects the central nervous system. Selected lists of references are appended to individual chapters.

BIOCHEMISTRY OF THE DEVELOPING NERVOUS SYSTEM. Edited by H. Waelsch. xvii + 537 pp. Academic Press, New York, 1955. $11.50. The papers constituting these extensive proceedings of the First International Neurochemical symposium, held at Magdalen College, Oxford, July 13-17, 1954, are centered around the following topics: morphological and functional ontogeny, chemical composition, blood-brain barrier, metabolism of the developing brain, enzymatic differentiation, cellular chemistry, genetics, and hormonal factors. Discussions of individual presentations, a large amount of pictorial material in the text, and a subject and author index enhance the value of this vivid portrait of an active segment of neurochemistry.

CLASSIFICATION FOR MEDICAL AND VETERINARY LIBRARIES. By Cyril C. Barnard. viii + 279 pp. H. K. Lewis and Co., London, 1955. 4.4 s. The classificatory system, using letter combinations rather than numbers, was originally devised for the London School of Hygiene and Tropical medicine. In the second edition the notation was adapted for the use in general medical libraries. Realizing that it is hard to satisfy all customers, it may be noted that physical anthropology is placed in Class Z (Geography, anthropology, sociology), while works on growth and forms are put into Class B Natural Science), division J (Biology), subdivision M. Should roller skates be issued together with the stack permit in libraries using Mr. Barnard's system?

THE DYNAMIC EQUILIBRIUM OF BODY PROTEINS. By George H. Whipple. vi + 68 pp. Charles C. Thomas, Springfield, Ill., 1955. $3.25. A review of information on the interchange between the proteins in circulation, in extra-cellular fluid, in the cells, and in the reserve stores, with special reference to results obtained in the course of some 30 years of research at the Department of Pathology, University of Rochester.

THE FUNDAMENTALS OF X-RAY AND RADIUM PHYSICS. By Joseph Selman. xii + 340 pp. Charles C. Thomas, Springfield, Ill., 1954. $8.50. Based on materials used in the instruction of student X-ray technicians, the book covers relevant theoretical and practical aspects of radiological physics. It will be found useful by individuals who need an elementary introduction to the subject.

GRAPHIQUES DE CROISSANCE DES ÉLÈVES DES ÉCOLES DE BRUXELLES. Institut Royal des Sciences Naturelles de Belgique. (no date) Instructions (6 pp.), in French and in Flemish, concerning the use of graphs for the evaluation of growth in reference to skeletal size (height), body weight, and musculature (estimated from a sum of the circumferences of the upper arm, with the forearm extended and flexed, and calf, not corrected for subcutaneous adipose tissue). Ages 6 to 15, males and females. In height-weight graphs the zones including the middle 70, next 25, 4 and 1% are indicated by eliptoid curves. Average values for adjacent ages are indicated.

HANDBOOK OF VITAL STATISTICS. Statistical Office of the United Nations. iv + 258 pp. United Nations, New York, 1955, $2.50. Information on births and deaths, on marriages and divorces, is required as a basis for developing more effective socio-economic policies and represents an important tool of epidemiological research. The purpose of the Handbook is "to explore current practices, to make conveniently available recommended statistical standards, and to present uniform concepts, definitions, and procedures upon which development of national vital statistics and the improvement of their international comparability may be based."

THE PHYSIOLOGY OF DOMESTIC ANIMALS. By H. H. Dukes. xii + 1020 pp. Cornell Univ. Press, Ithaca, New York, 1955. $9.75. A standard textbook in the field of animal physiology, designed for students of veterinary medicine and animal husbandry. The volume, now in its 7th edition, underwent an extensive revision and was supplemented with several new chapters, including M. R. Kare's chapter in which fluid compartments of the body are briefly discussed. Six pages are devoted to growth.

PHYSIOLOGY AND PATHOLOGY OF INFANT NUTRITION. By L. F. Meyer and Erich Nassau. ix + 533 pp. Charles C. Thomas, Springfield, Ill., 1955. $11.50. Intended for the medical student and the practicing physician, the book contains a section on physical growth (pp. 6-41), including the development of adipose tissues (pp. 32-37), a chapter on the characterization of the nutritional state (eutrophy, dystrophy, atrophy), and on constitution and nutrition.

PRESENT KNOWLEDGE IN NUTRITION. By the Editorial Staff and Advisory Board, Nutrition Reviews. 130 pp. The Nutrition Foundation, New York, 1956. The second revised edition of a useful monograph based on articles previously published in the journal *Nutrition Reviews*, focussed on the major organic foodstuffs, minerals, and vitamins.

RADIOSOTOPE CONFERENCE, 1954. Vol. I. Edited by J. E. Johnston. xi + 418 pp.

Academic Press, New York, 1954. $10.80. The first volume of the proceedings of a conference sponsored by the Atomic Research Establishment, Harwell, England, and held in July 1954, contains 46 papers devoted to medical and physiological applications (therapy, diagnosis, animal physiology and pathology, biochemistry, plant nutrition). Subject index is lacking. The use of radioisotope techniques for the study of body composition *in vivo* was not discussed.

RADIOISTOPES IN BIOLOGY AND AGRICULTURE. By C. L. Comar. xiii + 481 pp. McGraw-Hill Book Co., New York, 1955. $9.00. The publication, addressed to the student and the investigator, summarizes in one volume the basic information needed in radioisotope tracer studies. The more general aspects of tracer methodology, properties and usage of individual radioisotopes, and specific procedures (autoradiography, paper chromatography, ion exchange, radioactivation analysis) are presented in turn. Several appendixes, including a glossary, increase the practical value of this book. Exploration of the labyrinths of intermediary metabolism, autoradiographic study of deposition of Ca^{45} in reference to bony structure, and radiocarbon dating indicate the wide range of applicability of radioisotope techniques.

A SHORT HISTORY OF MEDICINE. By Erwin H. Ackerknecht. xviii + 258 pp. Ronald Press Co., New York, 1955. $4.50. A readable presentation of a complex subject. Last 100 pages are devoted to the developments since the beginning of the 19th century. Throughout, the author makes a conscious effort not to fall into the pattern of purely cataloguing names and events. Separate chapters are devoted to medicine in the United States prior to 1900 and to the main trends in the 20th century. The list of selected readings emphasizes reprints and translations of medical classics.

SOCIETY AND MEDICINE. The New York Academy of Medicine. Edited by Iago Galdston. International Universities Press, New York, 1955. $3.00. A collection of essays on a variety of subjects, including the biology of ethics (R. W. Gerard), natural history of neurotic behavior (H. S. Liddell), enviroment and heredity (T. H. Ingalls), and effects of food on health (R. M. Wilder).

University of Minnesota,
Minneapolis, Minnesota

JOSEF BROŽEK

CONTENTS (Continued)

THE CANADIAN WEIGHT-HEIGHT SURVEY. *L. B. Pett and G. F. Ogilvie* 177

ANTHROPOMETRY AND NUTRITIONAL STATUS OF ADULT WOMEN. *Margaret A. Ohlson, Alice Biester, W. D. Brewer, Betty E. Hawthorne and Marie Bohland Hutchinson* 189

OBESITY AND DISEASE. *Arnold B. Kurlander, Sidney Abraham and J. Wallace Rion* 203

BODY WEIGHT: FACTS FROM LIFE INSURANCE RECORDS. *Herbert H. Marks* 217

FAT THICKNESS AND GROWTH PROGRESS DURING INFANCY. *Stanley Marion Garn with the assistance of Georgia R. Greaney and Richard W. Young* 232

COMMENTS. *Werner Kornfeld* 251

COMMENTS. *R. F. A. Dean* 252

ALLOMETRIC GROWTH OF BODY COMPOSITION IN MAN AND OTHER MAMMALS. *Edward E. Hunt, Jr. and Eugene Giles* 253

BOOK REVIEWS 274

BOOK NOTICES 286

Human Biology

a record of research

VOLUME 28 MAY 1956 NUMBER 2

CONTENTS

INTRODUCTION. *W. W. Howells* 109

RECOMMENDATIONS CONCERNING BODY MEASUREMENTS FOR THE CHARACTERIZATION OF NUTRITIONAL STATUS. Committee on Nutritional Anthropometry, Food and Nutrition Board, National Research Council, *A. Keys*, Chairman 111

PHYSIQUE AND NUTRITIONAL STATUS OF ADULT MEN. *Josef Brožek* 124

BODY BUILD AND BODY WEIGHT IN 25-YEAR-OLD ARMY MEN. *Robert M. White* 141

VARIABLE FACTORS IN SKELETON WEIGHT. *Mildred Trotter* 146

SKINFOLD MEASUREMENTS IN YOUNG AMERICAN MALES. *Russell W. Newman* 154

CORRELATIONS BETWEEN THICKNESS OF SKINFOLDS AND BODY DENSITY IN 88 SOLDIERS. *Luke R. Pascale, Morton I. Grossman, Harry S. Sloane and Toby Frankel* 165

(*Continued on Inside of Cover*)

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GABRIEL W. LASKER

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JAMES N. SPUHLER
WILLIAM L. STRAUS, JR.

Review Editor
JOSEF BROŽEK

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LIBRARY

BODY COMPOSITION IN CHILDHOOD *

WITH REFERENCE TO *IN VIVO* CHEMICAL ANALYSIS OF WATER, FAT, AND PROTOPLASMIC MASS

BY ICIE G. MACY AND HARRIET J. KELLY
The Merrill-Palmer School, Detroit, Michigan

THE study of child development is handicapped because of inadequate information on the chemical composition of the body and on the components of body weight gain or loss during growth and maturation. Knowledge of body composition has major significance in health and disease and, therefore, in the care of children.

As the body moves toward maturity and completion of physical structure, with consequent adaptation in physiologic function, the individual tissues and the organism as a whole must progressively change to accommodate for symmetry of physical and chemical growth if homeostasis and satisfactory nutriture of the body are to be maintained. It is generally understood that the body is dynamic in character, that the

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* This work was supported in part by grants from the Williams-Waterman Fund, The Nutrition Foundation, Inc., The Kresge Foundation, Swift and Company, and the National Institute of Health for the Study of Rheumatic Diseases.

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modification of the composition of the body is subject to constant physicochemical fluctuations, and that a given unit increment in weight, stature, or chemical composition may be entirely different at one stage of development from the unit increment at another. For instance, in the infant a gain of 1 kg in weight means in large measure an increase in neural, glandular, and muscle tissues composed of a large proportion of active protoplasmic cell mass (Harris *et al.*, '30), whereas in the child the gain is primarily due to bone and muscle, and in the adult it usually indicates the accumulation of body fat (Behnke, '41-'42, Behnke *et al.*, '42, Osserman *et al.*, '50, Keys *et al.*, '50, Widdowson *et al.*, '51, McCance and Widdowson, '51, Miller and Blyth, '52). More specific information on body composition in childhood and on the effect of the usual growth and maturation processes is urgently needed to bridge an essential gap in our knowledge of child development.

The fact that few data on the direct chemical analyses of total or even parts of human bodies are available is due to the difficulty of obtaining bodies for analysis and to the many, almost insurmountable tasks involved in handling and sampling accurately such large quantities of diffuse biological materials. The individuals reaching autopsy and made available to the biochemist for direct chemical analysis too frequently have had questionable health records; hence the data resulting from the determinations may not represent normal body composition values. More fetuses have been subjected to chemical analyses than infants, children, or adults. Widdowson, McCance, and Spray ('51) recently presented new data and summarized existing knowledge on the chemical composition of human bodies. In presenting the major chemical components of the body of a male child 4½ years old, with a body weight of 14.0 kg and a height of 107 cm., these investigators point out that, although the results of the analyses are of great value to physiologists and pathologists, "the findings require cautious interpretation if they are to be used as the basis of normality." They emphasize that "many more bodies will have to be analyzed to establish reliable figures for the normal average and its variation."

The importance of quantitative evaluation of body weight with special reference to fat, fat-free mass, water, and minerals was stressed by Moulton ('23) and Hastings ('40-'41) in their classic studies of chemical composition of body tissues of animals. Numerous investigators have demonstrated that the relative fatness of adults of the same species does not affect the composition of the fat-free body mass. Moulton discovered three decades ago that the concentration of water, protein, and ash of the fat-free body mass becomes more or less stationary, after which no appreciable changes occur; he described this state of body composition as *chemical maturity*. Applying the results obtained on animals to human individuals, Moulton surmised that by early childhood the fat-free protoplasmic mass has reached a more or less constant chemical composition. This theory is supported by belief that growth and development are most stable between the ages of 4 and 9 years.

In later systematic work involving detailed analyses of whole bodies of several species of mammals at various ages, including man, Spray and Widdowson ('50) point out that mammals similar morphologically have similar composition and that the term *chemical maturity* can be applied to the body as a whole only when all its constituents have reached constant level. In a recent report on continuing studies of linear growth of long bones (Maresh, '55), it is stated that "beginning at about three or four years of age and continuing to the prepubescent years, the childhood patterns of long-bone growth were found to be remarkably stable and orderly. Here the changes in percentile levels with increasing age were minimal, fluctuations were few, and the growth curves for all four bones [humerus, radius, femur, and tibia] were usually alike descriptively. 'Latency' would seem to be a good term for linear physical growth in the childhood years."

During the Second World War the urgent need for improved preparation and care of military personnel stimulated intensive research on body composition for *in vivo* chemical analysis of the human body. Under the able leadership of Behnke ('41-'42), investigations were designed which resulted in practical procedures for partitioning the body weight of living adult men and women into its principal components—water, fat, and lean body mass. The results have been extended and verified in principle by other investigators (Keys *et al.*, '50, McCance and Widdowson, '51, Miller and Blyth, '52), and they agree in general with the few data obtained by direct chemical analysis of human bodies (Widdowson *et al.*, '51, Forbes *et al.*, '53, Mitchell *et al.*, '45).

The purpose of this paper is to apply similar methodologies and to adapt them for partitioning body weight of living children into fat, total body water, extracellular water, intracellular water, and lean body mass. In this way body composition in childhood can be predicted with reasonable accuracy in relation to physical and chemical growth and to maturation. A battery of tests were made, including anthropometric measurements, roentgenographic assessments of skeletal maturation, and biochemical studies of urine, physiologic functions and basal oxygen consumption. These tests served as the basis for assessing the body composition of active, healthy children. The fact that so many independent evaluations were made, both direct and indirect, provided a check on the methods used and the values obtained.

EXPERIMENTAL

This report on the assessment of body composition in childhood is an extension of the investigation recorded in *Nutrition and Chemical Growth in Childhood* (Macy, '42, '46, '51). The description of the children, the environmental conditions and controls, and the tests applied are recorded in detail in Vol. 1—*Evaluation* (Macy, '42), Vol. 2—*Original Data* (Macy '46), and Vol. 3—*Calculated Data* (Macy, '51). The children selected and observed throughout childhood were those whose medical records showed a minimum of illnesses, none of which were extensive or severe, and the absence of known untoward hereditary factors in their medical histories; who were normal in weight for height by the standards of Meredith ('35) and Boynton ('36); and whose roentgenograms indicated skeletal development and maturity within normal limits (Macy, '42, '46, '51). The methodologies used as the basis of physical and chemical growth and maturation are shown in table 1. Childhood refers to the years between the ages of 4 and 12.

TABLE 1

Methodologies used in growth studies

Anthropometric Measurements

Weight
Length: Total body, stem, tibia, head
Width: Biacromial (shoulder), intercristal (hip), intertrochanteric (hip); head, chest
Depth: Chest
Circumference: Head, chest, upper arm, thigh, abdomen
Subcutaneous tissue: Fat over biceps

Roentgenologic Maturity Assessments

Hand
Shoulder
Elbow
Foot
Knee
Hip

Biochemical Studies

Urinary excretion of total nitrogen and creatinine
Basal metabolic rate

Investigators studying body composition have used various terms for those components of body weight that are associated with the active protoplasmic mass or cell mass. In this discussion, *lean body mass* is composed of extracellular water, intracellular water, and cell solids. *Cell solids* equals lean body mass minus total body water (extracellular and intracellular). Fat equals gross body weight minus lean body mass.

Some adjustments have been made in the calculations to correct for differences in terminology. Lean body mass, as used in this paper, contains no fat. In Behnke's definition ('41-'42) of this term, a certain amount of "essential" fat is included. Therefore, when Behnke's equations were applied, his lean body mass values were adjusted to eliminate the 10% essential fat for boys and the 15% for girls that he had included. In our values, this "essential" fat is included in total body fat, which makes our figures for total fat appear higher than those reported by Behnke.

Cell mass is used by some investigators. It may be obtained in one of two ways: (1) lean body mass minus extracellular water; (2) cell solids plus intracellular water.

RESULTS

The results of this investigation contribute to a more specific evaluation of the principal body components in childhood—total body water (including its integral parts, extracellular and intracellular water), fat, and lean body mass.

Body Water Evaluation. Water is essential for the construction, function, and maintenance of the homeostatic condition of the body. The physicochemical reactions, on which cellular function and life depend, take place in the presence of water and are affected by fluctuations in the water content of the body. Three methods have been employed in the estimation of the volume of water in the body: (1) chemical analysis by the desiccation procedure applied after death (Widdowson *et al.*, '51, Spray and Widdowson, '50, Forbes *et al.*, '53, Mitchell *et al.*, '45); (2) *in vivo* dilution procedures employing a variety of chemical substances (Pace *et al.*, '47), Soberman, '49, Steele *et al.*, '50, Kraybill *et al.*, '51); and (3) the method of water displacement for determining the specific gravity of living persons and cadavers (Behnke, '41-42, Zook, '32, Boyd, '33, Brožek *et al.*, '49).

The equations derived by Friis-Hansen *et al.* ('51) for determining the volume of total body water of children were directly applicable to the assay of the body composition of our children. Their technique utilized the dilution method with either deuterium oxide or antipyrine or both, and the equations developed took into account, first, weight, and second, surface area as follows:

$$\text{Total body water} = 0.55 \times \text{weight} + 0.51 \qquad SD = \pm 7.4\% \quad (1)$$

$$\text{Total body water} = 15.05 \times \text{surface area} - 0.71 \qquad SD = \pm 7.1\% \quad (2)$$

Total body water is given in liters, weight in kilograms, and surface area in square meters, as determined by DuBois' formula ('16). Application of the first equation to the data accumulated on the children in this report gave for relative body water composition a value ranging from 56 to 58%, whereas the second equation, which takes into account body size or surface area, gave a somewhat wider range of 46 to 58%. These values are presented in table 2.

TABLE 2

Estimated total body water in body weight in childhood

PROCEDURE USED	REFERENCE	RANGE OF TOTAL BODY WATER Kilograms	RANGE OF TOTAL BODY WATER Percent of Body weight
Derived from studies on children:			
Predicted from body weight	Friis-Hansen *et al.*, '51	9.6–23.6	56–58
Predicted from surface area *	Friis-Hansen *et al.*, '51	9.6–20.1	46–58
Adapted from studies of adults:			
Based on chronologic age	McCance and Widdowson, '51	9.9–24.6	56–62
Based on anatomic age	McCance and Widdowson, '51	9.9–25.4	56–62

* Although the predictions from body weight and surface area were made on the same group of children, the minimum absolute values represent two different children in the group, which accounts for the apparent discrepancy in relative values.

By means of an independent biochemical procedure, McCance and Widdowson ('51) developed the following equation for adults:

$$\text{Total body water} = \text{extracellular water} + 67\% \text{ cell mass.}$$

The prediction equations for the amounts of extracellular water, cell mass, and fat were formulated by the method of least squares, from data given by these investigators, utilizing *relative* body weight status instead of actual or gross body weight. In applying these prediction equations to children, the relative body weight status values were derived from the standard values developed by Pryor ('43). These norms were arrived at by use of several measurements, namely, sex, age, height, hip breadth, and chest breadth. The prediction equations used in calculating values for our children were as follows for boys:

$$\text{Extracellular water } (\%\text{ body weight}) = -0.16 \times \%\text{ normal weight} + 36.64.$$

$$\text{Cell mass } (\%\text{ body weight}) = -0.16 \times \%\text{ normal weight} + 72.69.$$

and for girls:

$$\text{Extracellular water } (\%\text{ body weight}) = -0.11 \times \%\text{ normal weight} + 33.85.$$

$$\text{Cell mass } (\%\text{ body weight}) = -0.16 \times \%\text{ normal weight} + 70.56.$$

Normal weight was estimated by both chronologic and anatomic ages. When measurements of body size or composition are based on age, anatomic or skeletal age often gives a truer evaluation. For this reason, the percentages of total body water are presented for both chronologic and skeletal ages (table 2). On the basis of chronologic age the results obtained for total water amounted to 56 to 62% of the body weight and were comparable to the range of 46 to 58% derived from the equations of Friis-Hansen *et al.* ('51). On the basis of anatomic age, the substituted equation of McCance and Widdowson ('51) produced similar values of 56 to 62% total body water.

Edelman *et al.* ('52) determined total body water in normal human human beings of both sexes throughout the life span by using the deuterium oxide dilution technique. One hundred and twenty measurements were made on subjects two days to 86 years of age with a weight range of 2.3 to 100.3 kg. No appreciable difference attributable to sex was noted until the age of 16 years; thereafter the mean body water was lower in the females studied than in the males of corresponding age. The ranges of total body water determined were 55.2 to 62.8% of body weight from one to 9 years, 51.8 to 63.2% for males from 10 to 16 years, and 49.8 to 59.5% for females 10 to 16 years of age.

The estimates of body water in childhood presented in table 2 fall within the range found by Edelman *et al.* ('52) for normal childhood. Further confirmation is thus given to the values obtained in our study of nutrition and chemical growth in childhood, inasmuch as the volumes of water compare favorably with the results obtained by direct analysis by desiccation of the cadaver of a 4½-year-old child (Widdowson *et al.*, '51). The percentage of water in the whole body of the child on a fresh weight basis amounted to 53.8, which was somewhat lower than the values for childhood determined in our studies, no doubt because the child had been ill for two weeks prior to death and its body water had been reduced some by dehydration.

Extracellular Water Evaluation. Manery ('54) described extracellular fluid as "an ill-defined physiological unit made up of plasma, lymph, cavity extracellular fluids and interstitial fluid of tissues. Each type resembles the plasma in a general way but each one is dissimilar to the plasma and to all others in a fashion depending upon the site and function of the particular tissue of which it is a part." He also distinguished anatomic and physiologic measurements of extracellular water. On a practical basis, the usual determination of extracellular water falls somewhere between the anatomic and physiologic measurements and is the value most generally obtained with present clinical procedures.

Morse *et al.* ('47) studied 65 normal healthy children, aged three to 17 years, and determined available fluid volume by the sodium thiocyanate dilution method. By the method of least squares these investigators obtained the following equations:

For children with surface areas of 0.5 to 1.2 square meters:

$$\text{Available fluid volume} = -6.14 + 0.1042 \text{ height (cm)}.$$
$$\text{Available fluid volume} = -1.48 + 9.12 \text{ surface area (sq. m.)}.$$

For children with surface areas of 1.0 to 2.0 square meters:

$$\text{Available fluid volume} = -27.20 + 0.2557 \text{ height (cm)}.$$
$$\text{Available fluid volume} = -7.15 + 14.22 \text{ surface area (sq. m.)}.$$

For the whole range of childhood and adolescence:

$$\text{Available fluid volume} = -0.03 + 0.287 \text{ weight (kg)}.$$

On the assumption that the available fluid volume may be considered equivalent to extracellular fluid, we applied these equations to the data recorded in *Nutrition and Chemical Growth in Childhood.* When the results obtained on the basis of height, weight, and surface area were averaged, from 25 to 30% of the body weight was estimated to be extracellular water (table 3).

TABLE 3

Estimated extracellular and intracellular water in body weight in childhood

PROCEDURE USED	REFERENCE	RANGE OF WATER Kilograms	Percent of Body water
Extracellular water			
Derived from studies on children:			
Predicted from height, weight and surface area	Morse *et al.*, '47	4.7–12.6	25–30
Predicted from weight and surface area	Friis-Hansen *et al.*, '51, Gamble, '47	2.7– 6.2	15–17
Predicted from weight and surface area	McCance and Widdowson, '51, Friis-Hansen *et al.*, '51	3.5– 8.0	19–21
Adapted from studies on adults:			
Based on chronologic age	McCance and Widdowson, '51	3.6– 8.6	19–24
Based on anatomic age	McCance and Widdowson, '51	3.7– 9.2	19–24
Intracellular water			
Derived from studies on children:			
Predicted from weight and surface area	Friis-Hansen *et al.*, '51, Gamble, '47	6.9–15.6	37–42
Predicted from weight and surface area	McCance and Widdowson, '51, Friis-Hansen *et al.*, '51	6.1–13.8	33–37
Adapted from studies on adults:			
Based on chronologic age	McCance and Widdowson, '51	6.1–15.9	35–40
Based on anatomic age	McCance and Widdowson, '51	6.1–16.3	35–39

McCance and Widdowson ('51) developed a simplified method of obtaining body composition which is applicable to living persons in health and disease. According to their thesis, the body is in large measure composed of total body water, extracellular water, cell mass, fat, and minerals. They determined body water by the dilution procedure. In the extracellular fluid determinations, sodium thiocyanate was used and the corrections were made for its penetration into the erythrocytes. The prediction equation for evaluating the volume of extracellular water in the body, as given above, was derived from the data of McCance and Widdowson by the method of least squares.

The relative amounts of extracellular water of the body during childhood are recorded with respect to both chronologic and anatomic ages in determining normal weight (table 3). The extracellular water was found to occupy 19 to 24% of the body weight whether the prediction equation was referred to chronologic or to anatomic age.

The relative volumes of extracellular water determined by the prediction equation developed from McCance and Widdowson's data on adult men and women gave lower levels than those obtained by the equation of Morse *et al.*, namely, 19 to 24% and 25 to 30% of body weight, respectively. These differences could be accounted for by the possibility that Morse *et al.* made no correction for the penetration of the sodium thiocyanate into the erythrocytes; or the discrepancies may have originated in the application of equations derived for adults to measurements of extracellular fluid in children.

Intracellular Water Evaluation. McCance and Widdowson ('51) measured the amount of cell mass and extracellular water and, assuming that the cells contained 67% by weight of water, calculated the intracellular water. The average summary values derived by this procedure gave results of 59% for total body water, 21% for extracellular water and 38% for intracellular water of body weight in childhood. These values agree closely with those obtained by the use of the Friis-Hansen *et al.* data on total body water which gave average values of 55% total body water, 20% extracellular water, 35% intracellular water of body weight in childhood. Edelman obtained 59% total body water in childhood.

Body Fat Evaluation. In a review of the general subject of the estimation of fat in the body Brožek and Keys ('50) state that "while the present orientation is toward nutritional application, it should be observed that estimation of the proportion of fat in the human body is needed for an intelligent interpretation of body weight and its change in different physiological conditions; for the investigation of differential rates of growth and involution of body tissues during the life cycle; for a quantitative description of the physical constitution and 'body type,' especially with reference to morbidity and mortality trends; and for the study of sex and race differences."

Direct measurements of specific gravity of adult men (Behnke, '41-'42, Osserman *et al.*, '50, Keys *et al.*, '50, Messinger and Steele, '49) and children (Zook, '32, Boyd, '33) demonstrated that fat, with its low density (0.92 specific gravity), is the primary variable which determines individual body density. Studies of total body specific gravity led Behnke ('41-'42) and co-workers (Morales *et al.*, '45, Pace and Rathbun, '45) to the conclusion that the living body can be divided into a "fat-free" portion (lean body mass) of constant gross composition (which includes a certain amount of essential fat) and a variable quantity of fat. Since lean body mass may be considered to be relatively constant with respect to water content for the same species, age, and sex (Widdowson *et al.*, '51, Morales *et al.*, '45), it is possible to estimate total body water from fat content and, conversely, total body fat from water content (Widdowson *et al.*, '51, Morales *et al.*, '45, Steele, '50). Calculations were based on 71.8 to 73.2% water in the lean body mass.

Body water by the antipyrine dilution method (Steele, '50, Keys and Brožek, '53) and specific gravity by the method of underwater weighing have been determined on the same men (Osserman *et al.*, '50, Messinger and Steele, '49). The two independent methods of assay gave closely agreeing results for total body water and total body fat. According to some investigators, the substitution of the antipyrine method for specific gravity measurement is considered a valid means of eliminating the subject cooperation required by underwater weighing.

In a study of the human body during infancy, childhood, and adolescence, Boyd ('33) related specific gravity to stature and to age. For children at mid-respiration she derived the following equations:

$$\text{Specific gravity} = 0.95431 + 0.000402 \times \text{stature (cm)}.$$
$$\text{Specific gravity} = 0.98705 + 0.002218 \times \text{age (years)}.$$

When these equations were applied to our data in *Nutrition and Chemical Growth in Childhood*, good agreement was found between specific gravity on the basis of stature and on the basis of age. The average values for specific gravity derived from the study of Zook ('32) on 164 boys, aged 5 to 19 years, agree with those presented by Boyd. In determining the specific gravity values with which to calculate the body composition of our children, the results obtained by Boyd were averaged with the smoothed values for the boys in Zook's study. The calculated specific gravity of our children give a range between 0.999 and 1.015 (table 4).

TABLE 4

Estimated fat content of body weight in childhood *

PROCEDURE USED	REFERENCE	RANGE OF FAT CONTENT Kilograms	 Percent of Body weight
Derived from studies on children:	Friis-Hansen *et al.*, '51	3.5–12.2	21–29
Adapted from studies on adults:			
Using standard weight			
Based on chronologic age	McCance and Widdowson, '51	2.5– 7.0	12–21
Based on anatomic age	McCance and Widdowson, '51	2.4– 7.1	12–23
Using urinary creatinine			
Based on chronologic age	Miller and Blyth, '52	2.7– 9.9	13–31
Based on anatomic age	Miller and Blyth, '52	2.7– 2.9	13–31

* Specific gravity predicted from stature and age ranged from 0.999 to 1.015, with an average of 1.005.

Estimations of body fat *in vivo* were also made from total body water by means of equations developed for children as well as equations developed for adults and adapted to children. The following prediction equation for the amount of fat was formulated by the method of least squares from data on adults given by McCance and Widdowson ('51) utilizing relative weight status:

$$\text{Fat } (\% \text{ of body weight}) = 0.34 \times \% \text{ of normal weight} - 17.60.$$

From the equations for children, the fat content of the body of our children ranged from 21 to 29% of the body weight, as shown in table 4. Methods developed on adults, including the use of formulas based on standard weight and creatinine excretion data, gave results in fair agreement. It will be noted that values obtained by independent methods gave a range of 12 to 31% fat in the body weight of our children. Although this amount of fat is important when considering the composition of body weight, the results correspond with the estimated specific gravity and subcutaneous fat findings in indicating that our children possessed a moderate amount of body fat, in view of the fact that these values include a certain amount of essential fat.

Numerous tests demonstrated that our children were well nourished but were not obese by any of the standards used. On the basis of chronologic age their weight range was from 86 to 110% of the standard weights, and a similar range was obtained on the basis of anatomic age. When measured by the skinfold method on the biceps in accordance with the Franzen ('29) technique, they showed a range of 78 to 155% of subcutaneous tissue, which indicates moderate fatness. The retention of the total electropositive and electronegative minerals by the children indicated that their change in body weight was due to increase in lean body mass and not to excess body fat or water.

Lean Body Mass Evaluation. Lean body mass may be estimated in the living subject by several independent methods, such as measurements of oxygen consumption, urinary excretion of creatinine per 24 hours, urinary nitrogen excretion, and storage of nitrogen by the metabolic balance method. Basal metabolic rate and creatinine excretion have long been associated with that amount of protoplasmic tissue present in the body, although individual tissues composing the total protoplasm in the body consume oxygen at characteristic but at dissimilar rates. A close relationship would be expected, therefore, between the total amount of lean body mass and the oxygen consumption and the urinary creatinine excreted, referred to a square meter of body surface area. Assuming that the relative composition of the lean body mass is on the average the same during childhood and adulthood, we adapted the equation developed by Miller and Blyth ('52) to children, using the determined values of basal oxygen consumption:

$$\text{Lean body mass} = \text{standard weight}\left(-0.08943 + \frac{0.92674\ \text{oxygen consumed}}{\text{oxygen standard}}\right).$$

The standard values employed for oxygen consumption were those of Lewis *et al.* ('43) and Kenyon *et al.* ('54). The results on the basis of chronologic age showed that the children of *Nutrition and Chemical Growth in Childhood* possessed 69 to 88% of their body weight in lean body mass, and on the basis of skeletal age 69 to 92% (table 5). The percent of lean body mass obtained by this procedure was comparable to the values obtained by methods involving the measurement of either body water or body fat. Behnke's data ('53) derived from adults were adapted for children by the following equations:

$$\text{Lean body mass} = \frac{\text{standard weight}}{46.54575}\left(\frac{74.1 \text{ Cal. hr.}^{-1}}{\text{Cal. hr.}^{-1}\text{ standard}} - \frac{35.26 \text{ height for boys}}{\text{standard height}}\right).$$

$$\text{Lean body mass} = \frac{\text{standard weight}}{34.20495}\left(\frac{61.98 \text{ Cal. hr.}^{-1}}{\text{Cal. hr.}^{-1}\text{ standard}} - \frac{29.25 \text{ height for girls}}{\text{standard height}}\right).$$

The results showed that 55 to 86% of the body weight of children was lean body mass.

TABLE 5

Estimated lean body mass in body weight in childhood

PROCEDURE USED	REFERENCE	RANGE OF TOTAL LEAN BODY MASS Kilograms	RANGE OF TOTAL LEAN BODY MASS Percent of Body weight
Derived from studies of body water of children	Friis-Hansen *et al.*, '51	13.1–29.8	71–79
Adapted from adult fat content:			
Based on chronologic age	McCance and Widdowson, '51	13.7–35.0	79–88
Based on anatomic age	McCance and Widdowson, '51	13.7–36.2	77–88
Adapted from adult oxygen consumption: *			
Based on chronologic age	Miller and Blyth, '52	15.5–35.7	71–88
Based on anatomic age	Miller and Blyth, '52	15.3–40.8	79–92
Based on height and weight	Behnke, '53	12.5–31.7	55–86
Adapted from adult urinary creatinine excretion studies:			
Based on chronologic age	Miller and Blyth, '52	14.5–31.9	69–87
Based on anatomic age	Miller and Blyth, '52	14.5–31.9	69–87

* These values are based on the range of averages of age groups, whereas the other values in the table represent the entire range for individuals.

A study of the urinary nitrogen excretion offers other means of evaluating body composition of children. Numerous investigators have found relationships between basal metabolic rate and urinary creatinine excretion rate when results are derived from body weight in kilograms, stature in cubic centimeters, and surface area in square meters. In evaluating the amount of lean body mass by means of creatinine excretion, we converted the equation of Miller and Blyth ('52) for adults to an equation for children:

$$\text{Lean body mass} = \text{standard weight}\left(0.2548 + \frac{0.51296\ \text{creatinine}}{\text{standard creatinine}}\right).$$

The standard creatinine values used were those of Clark *et al.* ('51). By this method of analysis of body weight composition, lean body mass ranged from 69 to 87% on the basis of chronologic age and from 69 to 87% according to skeletal age. The observed creatinine coefficient, in milligrams of preformed creatinine nitrogen per 24 hours divided by body weight, was constant within the range of 7.5 to 9.7. In estimating lean body mass from total body water, Friis-Hansen *et al.* ('51), we found the lean body mass to range from 71 to 79% of the body weight in childhood. Similar results were obtained by adapting the McCance and Widdowson ('51) studies on adults to children, giving values for lean body mass of 79 to 88% on the basis of chronologic age and 77 to 88% on the basis of anatomic age (table 5). Our values, estimated from the total body water data given by Edelman *et al.* ('52) using the factor 73.2, ranged between 68 and 86% lean body mass in the weight of normal children. They compare favorably with the results of 55 to 86% lean body mass obtained by applying Behnke's ('53) equation based on oxygen consumption, height and weight and adjusted for 10 to 15% essential fat, although the latter range varies more widely.

In this study of the body composition of children, we arbitrarily chose the average value of 73.2% to represent the total water in the fat-free body of children in preference to lower values (70 to 71.8%) employed by some investigators studying the body composition of adult men and women. Although the use of the higher factor for total body water in the fat-free body mass results in lower estimates of lean body mass and higher body fat, they are comparable to values arrived at by independent procedures.

The equations developed by Friis-Hansen *et al.* ('51) for children based on weight and surface area permit a study of body composition in relation to age trends. Table 6 demonstrates the trends in actual and relative body composition for boys and girls.

TABLE 6

Estimated body composition in childhood

	AVERAGE AGE GROUP				
	4–6 years		7–9 years		10–12 years
	Boys	Girls	Boys	Girls	Boys
Number of subjects	6	5	8	6	6
Weight, kg	18.5	16.4	24.8	25.4	34.1
Height, cm	109	105	127	125	141
Surface area, sq. m.	0.746	0.686	0.942	0.945	1.167
Total body water *	10.6 kg (57%)	9.6 kg (58%)	13.8 kg (56%)	14.0 kg (55%)	18.0 kg (53%)
Extracellular **	3.9 kg (21%)	3.5 kg (21%)	5.1 kg (21%)	5.1 kg (20%)	6.6 kg (19%)
Intracellular	6.7 kg (36%)	6.1 kg (37%)	8.7 kg (35%)	8.9 kg (35%)	11.4 kg (34%)
Lean body mass #	14.5 kg (78%)	13.1 kg (80%)	18.8 kg (76%)	19.1 kg (75%)	24.6 kg (72%)
Cell mass	10.6 kg (57%)	9.6 kg (59%)	13.7 kg (55%)	14.0 kg (55%)	18.0 kg (53%)
Cell solids	3.9 kg (21%)	3.5 kg (22%)	5.0 kg (20%)	5.1 kg (20%)	6.6 kg (19%)
Body fat	4.0 kg (22%)	3.3 kg (20%)	6.0 kg (24%)	6.3 kg (25%)	9.5 kg (28%)

* Equations for body water of children (Friis-Hansen *et al.*, 1951) based upon weight and surface area.

** Derived from total water by conversion factor of 21.7/59.

# Derived from total water on basis of 73.2% water in lean body mass.

The results on body composition of children reported in this study correspond favorably with the few direct chemical analyses that have been made on children's bodies after death. With the assumptions made, with the hazards incurred when procedures developed on adults are adapted and applied to children, and with the relatively few boys and girls observed at certain age levels, it seems more than chance that such close agreement was reached in the prediction of composition of body weight of living children through the use of independent direct and indirect physical and chemical measurements. The fact that so many independent evaluations were made, both direct and indirect, provided a check on the methods used and the values obtained.

The fact that successive observations were made and longitudinal data were accumulated on the same children throughout childhood while they were maintained on a known adequate diet and lived under favorable environmental conditions contributed to the accuracy of the determinations and measurements from which the predictions of body composition were made.

SUMMARY

The values for body composition of healthy living children presented here were acquired by several totally independent procedures and were based upon biochemical determinations, anthropometric measurements, skeletal maturation assessments, and physiologic functional tests. The observations were made on the same subjects during childhood (4 to 12 years) at the time they were adapting and maturing physiologically and physically in accordance with the demands of the growth impulse that was characteristic for the individual.

The methodologies selected, applied directly or adapted for the prediction of the composition of body weight, gave the following average percentages of the major constituents of body weight for the period of childhood: total body water, 55% (extracellular water, 20%; intracellular water, 35%) fat, 25%; lean body mass, 75%. The average specific gravity for childhood was 1.005. These estimated values in terms of *in vivo* body composition provide information for use in integrating studies of physical and chemical growth, maturation, and nutrition of children. They will serve until such time when more exact measurements of each component of the body weight can be obtained on a large number of boys and girls at different age levels.

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SOME PHYSICAL PECULIARITIES OF DEAF-MUTE BOYS

BY BIN YAMAGUCHI

Department of Anthropology, Tokyo University, Japan

INTRODUCTION

IT is said that the abnormal is only a modification of the normal and that a hitherto unknown norm can be detected through a careful analysis of the abnormal. This study, dealing with deaf-mute boys, seeks to determine some peculiarities in their physical type and motor function. A further purpose is the possibility of obtaining some suggestions for the study of normal processes. The data used are abstracted from my unpublished master's dissertation (Yamaguchi, '55).

MATERIAL

Fifty-eight deaf-mute boys (15–17 years of age) from two schools for the deaf in Tokyo were measured and investigated in 1953-1955. With respect to cause and range of disease, the materials are somewhat heterogeneous. But, to my regret, the sample size is so small that I can only deal with them *en bloc.*

In order to obtain standard data for comparison, I carried out a similar investigation on 119 normal boys and 148 girls (15–17 years) of a high-school in Tokyo, whose average socio-economic status is very close to that of the deaf-mute boys.

METHOD

Measurement. Stature, arm length (acromion height—dactylion height), leg length (height of iliospinale), shoulder breadth (biacromial diameter), hip breadth (iliocristal diameter), circumferences of upper arm, wrist, and thigh, and subcutaneous fat thickness (skinfold on medial surface of upper-arm).

Motor function. *a.* Static balancing (duration of toe-standing on a bar with open eyes), *b.* reaction time (simple visual reaction time), *c.* manual dexterity (match-board test), *d.* finger dexterity (ball-picking test), *e.* motor speed of arm (tapping test), *f.* muscle strength (hand grip and Sargent jump), *g.* mimic muscle movement (closing one eye), and *h.* handedness (throwing hand).

FINDINGS

It would not be useful to record here the detailed figures of means and variances. The main results are illustrated in figure 1. Mean differences between deaf-mute and normal boys are represented by relative deviations of the former from the latter. So as to make clear the degree of divergence, the normal sex differences in physique are also figured.

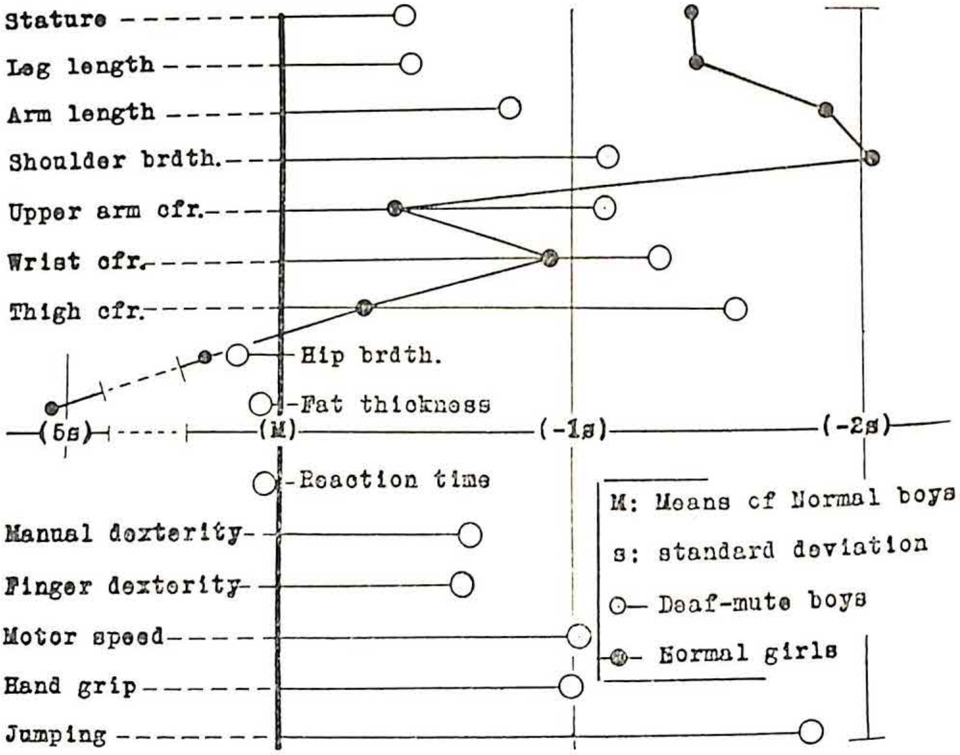

FIG. 1. RELATIVE DEVIATION OF DEAF-MUTE BOYS FROM NORMAL BOYS, IN PHYSIQUE AND MOTOR FUNCTIONS.

Physique. Whereas the deaf-mutes have slightly shorter limbs and stature, considerably narrower shoulders, and very slender arms and thighs (even more slender than in the normal girls), hip breadth and subcutaneous fat thickness are somewhat greater than in the normal boys. Thus, all of the nine measurements tend to approximate those of the normal girls.

Motor function. Static balancing ability is quite defective (table 1).

TABLE 1

Static balancing ability of deaf-mute and normal boys

	NO.	STANDING DURATION (IN SECONDS) 0–9″	10–x″	PERCENTAGE OF (10–x″)
Deaf-mute	58	53	5	9.4
Normal	119	19	100	84.0
		$P < .01$		

Correlation between balancing ability and the degree of hearing-loss is not so close as was expected ($r = .25$).

Except in reaction time, the deaf-mutes are significantly inferior in manual and finger dexterity, motor speed, hand grip and jumping (as seen in figure 1).

The deaf-mutes seem to be somewhat inferior in left eye-closing ($P = .20$) (table 2).

TABLE 2

The results of the eye-closing test

	NO.	EYE	UNSKILLFUL	SKILLFUL	PERCENTAGE OF SKILLFUL
Deaf-mute	54	right	26	28	51.9
		left	26	28	51.9
Normal	119	right	55	64	53.8
		left	43	76	63.9

Frequency of left-handedness is significantly higher in the deaf-mutes (table 3).

TABLE 3

Frequency of left-handedness

	NO.	LEFT-HANDED	PERCENTAGE
Deaf-mute	58	11	19.0
Normal	119	6	5.0
		$P < .01$	

DISCUSSION

Physique. Extreme smallness of the circumferential measures, especially of wrist girth, and more than normal thickness of fat clearly indicate the weakness of muscle and/or bone. In view of the well-known fact that excessive deposition of fat is usually controlled by muscular activities, the lack of ordinary body movement appears to be one of the factors leading to such a deviant development of the deaf-mute body.

Further, the general concept of the deaf-mute body form (that is, almost normally long and strikingly slender, but considerably adipose) reminds us of the physique resulting from retarded metabolism, as in the case of thyroid hypofunction. In this regard, it is also possible that the metabolism and action organs of normal people are, in every ordinary movement, repeatedly encouraged by labyrinthine (vestibular) stimuli via sympathetic nerve activity, and that a similar but lesser effect may be produced by auditory stimuli. Therefore, it would be quite natural for deaf-mutes, who lead rather inactive lives and receive neither vestibular nor auditory stimuli, to have lowered metabolic function and resulting physique of the type described above.

As shown in table 4, fat thickness and static balancing ability of

TABLE 4

Correlation between fat thickness and static balancing ability of deaf-mute boys

FAT THICKNESS (ABDOMINAL)	STATIC BALANCING BAD (0–2″)	STATIC BALANCING GOOD (3″–x)	TOTAL NUMBER
thin (x–8mm)	7	13	20
thick (9–x mm)	9	3	12
	$P = .033$		

the deaf-mutes are significantly correlated, and thus support this interpretation.

Moreover, some feminine tendencies may be noted not only in the absolute but in the relative measures (table 5).

TABLE 5

Hip-shoulder index and arm-leg index

	NORMAL BOYS	DEAF-MUTE BOYS	NORMAL GIRLS
Hip breadth/shoulder breadth	.712	.760	.784
Arm length/leg length	.812	.798	.798

These also can be interpreted as probably due to the lack of masculine, or active and catabolic tendencies in the deaf-mute metabolic and autonomic balance.

If these interpretations are correct, similar factors might be taken into account in analyzing the normal body form.

Motor functions. As most of the deaf-mute boys have defective labyrinths, they find static balancing very difficult. Jumping ability is reduced both by the defect in balancing and weakness of muscular development.

Reduced dexterity of manual and finger movements is inferred to be a result of an undifferentiated Broca's area in the brain, because lesion of the cerebral speech area is known to produce the symptom of apraxia (a kind of motor confusion) as well as motor aphasia.

It has been recognized in normal right-handed people that, while simple and automatic movements are performed equally well by both hands, intensive or integrative movements are performed better by the right hand than by the left. From this point of view, the right hands of the deaf-mutes which are normal in reaction time but quite weak in grip strength and other complex movements, can be compared to the left hands of normal people. The high frequency of left-handedness in deaf-mute people has long been known and is also noticeable in this sample. These data, together with the results of the eye-closing test, seem to reveal a lack of development of right-left differentiation in deaf-mute cerebral function, which is also confirmed by table 6.

TABLE 6

Left/right ratio of grip strength

	NO.	MEAN	s^2
Deaf-mute	57	95.63	207.2
Normal	115	90.48	76.0

$P < .05$ (according to Aspin's test)

From the above considerations, we are led to the conclusion that the motor function of the deaf-mute brain corresponds to that of the normal right hemisphere, which, lacking the speech area, is not so highly integrated as the left. This not only shows the closeness of relation between manual function and speech development, but will give some suggestions and perspectives for analysing the differentiation and evolution of human physical functions.

SUMMARY AND CONCLUSION

Physique and motor functions of the 58 deaf-mute boys were compared with those of normal boys and girls. The conclusions are as follows:

1) Body form of deaf-mutes, which is characterized by extremely slender limbs and thick subcutaneous fat, resembles that of persons whose metabolic rates are somehow lowered and thus approaches the feminine type. This seems to be a result of metabolic retardation caused by the generally sedentary nature of deaf-mute life.

2) Motor functions are generally lowered. Detailed study of the data has revealed a lack of development of the cerebral motor function, especially of functional right-left differentiation, which can be attributed to the lack of a speech area in the deaf-mute brain.

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THE RELATIONSHIP BETWEEN THE OCCUPATIONAL STATUS OF INDIVIDUALS AND THE SEX RATIO OF THEIR OFFSPRING[*]

BY HARRIETT L. FANCHER

Department of Zoology, University of Missouri,
Columbia, Missouri

IT is generally believed that sex in man is chromosomally determined. Cytological observations indicating the presence of two *X*-chromosomes in the female and an *X* and a *Y* chromosome in the male, as well as the typical inheritance of sex-linked characters, strongly support this view. The sporadic occurrence of pedigrees with unusual sex ratios or with abnormal sex types is ordinarily not considered to be contradiction to the above theory; such cases are, in fact, often explainable on the basis of simple *X*-*Y* sex determination.

Recently, however, Bernstein ('54) has proposed a new theory of sex determination for man. Based on the observation that males in "masculine" occupations have a higher percentage of male offspring than do those in "feminine" occupations, it is postulated that there exist genes for masculinity and femininity, a preponderance of one type over the other in an individual expressing itself phenotypically in the choice of occupation of that individual, on the one hand, and in the sex ratio of his offspring, on the other hand. Because the existence of such factors, acting either independently of an *X*-*Y* sex-determining system, or in conjunction with it, would provide a new insight into problems of sex determination in man, it was decided to make a study of the sexes of the children of parents in different occupations to ascertain whether the original observations that sex ratio of offspring was correlated with occupational status could be repeated.

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FATHER'S EFFECT ON SEX RATIO

a. Method. The 1954 edition of *Who's Who in America* provided the basic data for this analysis. A tabulation was made of the sexes of children, in the order in which they were given, for the occupational groups listed below. The names of the children were taken as indicative of their sex. This procedure, which, unfortunately, is the only feasible one, must be subject to some error since masculine names may be given to girls and vice versa. In those instances where an ambiguous name (Marian, Lynn, Jean) or an uncommon one (Zola, Leunis, Chlotele) made allocation to one sex difficult or impossible, the sibship in which it occurred was excluded from the tabulations. The frequency of such cases was about one in two hundred, the proportions removed from each occupational class being approximately equal.

b. Classification of Occupations. The relative masculinity of individuals in the occupations studied was arbitrarily taken as that given in the study of Terman ('36). The groups designated as masculine were: engineers (architects), bankers, business (manufacturers, salesmen), lawyers (judges); the groups designated as neutral were: teachers (professors, scientific workers, college executives), doctors (dentists, psychiatrists, etc.); and the groups designated as feminine were: authors (artists, musicians, editors), and clergy. In any case where an individual could not be assigned to one of the above groups (as, for instance, an undertaker who might be considered a businessman, and therefore masculine, a professional worker, and therefore neutral, or an artist, and therefore feminine), his progeny were excluded from the tabulations.

c. Results. Table 1 gives the sex ratios for the various occupational groups. A Chi-square test for heterogeneity reveals no significant differences from expectation, either when the values are considered individually ($0.2 > P > 0.1$) or when they are grouped into masculine, neutral, and feminine classes ($P > 0.3$). Not only do the data fail to substantiate the previously described correlation of masculinity of the father with sex ratio, but there is not even a trend in that direction, despite the fact that the total numbers here (49,600) are considerably larger than those of the earlier studies cited above (8,400).

It is of considerable interest to point out here the rather remarkable agreement between the overall sex ratio arrived at by this method, .5194, and that obtained from birth data from the Bureau of Vital Statistics,

.5142. This serves to validate the method and suggests that errors in classifying the sex of children by their names must be rather infrequent and largely compensatory.

TABLE 1

Sex ratios for various occupational groups

OCCUPATIONAL GROUP	TOTAL NUMBER OF BOYS	TOTAL NUMBER OF GIRLS	SEX RATIO
Masculine			
Law	1624	1550	.512
Business	4106	3757	.523
Bankers	1736	1684	.508
Engineers	2199	1937	.531
Total	9665	8928	.520
Neutral			
Teachers	8923	8373	.516
Doctors	2405	2191	.524
Total	11328	10564	.517
Feminine			
Authors	3008	2654	.531
Clergy	1779	1709	.511
Total	4787	4363	.523
Overall Total	25780	23855	.519

MOTHER'S EFFECT ON SEX RATIO

a. Method. The source of the data here was *Who's Who among American Women*, 1939 edition. The considerations mentioned above with respect to the classification of the sex of offspring apply here also.

b. Classification of Occupation. Women were classified as masculine or feminine according to Terman's rating of their occupational group. The groups classified as masculine were: scientists, business women, lawyers, lecturers, educational executives, etc. The groups classified as feminine were artists, authors, teachers, etc. Excluded from consideration was the large group of clubwomen, since the decision as to the relative masculinity of their field of interest (as, for instance, politics versus flower arranging) could be highly subjective.

In most cases, the biographical sketch included the occupation of the husband so that he, also, could be classified as in the preceding study.

c. Results. Table 2 gives the sex distribution of offspring of women classified as masculine or feminine. There is no significant difference between the two groups; a Chi-square test gives a P value between .10 and .05. In any case, the direction of the deviation is opposite to that predicted by the hypothesis of masculinity and femininity factors.

TABLE 2

Sex distribution of offspring of women classified as masculine or feminine

	TOTAL NUMBER OF BOYS	TOTAL NUMBER OF GIRLS	SEX RATIO
Masculine	622	640	.493
Feminine	726	643	.530

For that smaller number of cases, where the classification of the male parent was also possible, the breakdown is given in table 3. Here again, the deviations in sex ratio of the three categories of males are not significantly different from the expectation based on the overall mean $(0.5 > P > 0.3)$.

TABLE 3

Sex ratios for masculine, feminine, and neutral breakdowns of husband's occupation in "Womens Who's Who"

	TOTAL NUMBER OF BOYS	TOTAL NUMBER OF GIRLS	SEX RATIO
Masculine	644	613	.512
Neutral	426	429	.498
Feminine	278	241	.536
Total	1348	1283	.512

DISTRIBUTION OF THE SEXES WITHIN FAMILIES

a. Method. Because the sex of each child was recorded in the order in which the children were named in the biographies, it was possible to enumerate the frequencies with which the different distributions occurred.

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They are given in table 4. The letter *B* represents a male birth, *G* a female birth, with their sequence indicating the order in which they are listed. (Excluded from this table are the single child familes of which there were 2259 with one boy and 2211 with one girl.)

Two deviations from expectation are obvious in the raw data, and prove to be significant when tested statistically. The first is the deficiency of like-sexed sibships in families of two, and the second is the excess, in families of three, of cases where the first two children are like-sexed. It may be surmised, as has been done by previous workers, that parents with two children of like sex are more likely to have a third child than are those with one of each sex.

TABLE 4

Distribution of children in families of size two through four

SEX OF FIRST TWO CHILDREN		*BB*	*BG*	*GB*	*GG*
Number of two-child families		2006	2161	2012	1715
Sex of third child in three-child families	*B*	771	597	576	648
	G	723	555	522	666
Sex of third and fourth children in four-child families	*BB*	177	143	138	133
	BG	161	117	116	127
	GB	123	132	124	127
	GG	148	143	107	125
Sexes of the first two children in families of sizes two to four		4109	3848	3595	3541

To differentiate between this hypothesis and the possibility that there is a non-random distribution of sexes in the first two children, it is necessary first to determine whether the distribution of the sexes of the first two children in all families agrees with the expectation. A simple binomial distribution of the form $p^2 + 2pq + q^2$ may not provide the appropriate expectations because the sex ratio is not the same for the first and second children. It is, however, possible to derive the sex ratios for the successive children from the data themselves, allowing for the insertion of this information into the expectations by decreasing the degrees of freedom in the statistical analysis. Thus, from table 4, the sex ratio of the first child is $(4109 + 3848)/15093$ and for the second $(4109 + 3595)/15093$, or .5272 and .5104, respectively. The expectations for the *BB*, *BG*, *GB*, and *GG* combinations then become (.5272)(.5104), (.5272)(.4896), (.4728)(.5104) and (.4728)(.4896), respectively. Multiplied by the total of 15093, these give expectations each of which differs from the corresponding observation by only 47.5, leading to a Chi-square value of 2.40 which, with one degree of freedom, corresponds to a *P* value between 0.2 and 0.1.

There is a slight (not significant) deviation in the direction of an excess of *BB* and *GG* combinations. There is one obvious source of this deviation: the occurrence of monozygotic twinning. Since the frequency of this type of twinning for the United States population is about three per 1000 (Enders and Stern, '48), it can be estimated that about 45 such cases should have occurred in the sample under consideration. Apportioning those among the *BB* and *GG* classes according to the sex ratio of the first birth (.5272) gives 24 *BB* and 21 *GG* twin pairs. The Chi-square analysis of the revised totals obtained by subtracting the estimate of the twins from the totals gives a *P* value between 0.3 and 0.2.

CONCLUSIONS

It has not been possible to confirm the observations of Bernstein that males and females in occupations classified as "masculine" have more male offspring than those in "feminine" occupations. The number of males in the analysis presented here has been about 6 times as large as that of the earlier work. No suggestion can be offered to account for the disagreement of the two analyses. In view of this lack of confirmation of an effect of masculinity on sex ratio, it would appear appropriate to retain, for the present at least, the concept of an *X*-*Y* sex-determining mechanism in man, without the influence of additional genetic factors.

As in previous studies, there appears to be a pronounced deficiency of like-sexed sibships of size two, and an excess over expectation of families of greater size in which the first two children are like-sexed. This is undoubtedly correctly interpreted as a greater tendency for parents with two children of like sex to have an additional offspring than for those with one child of each sex. However, when all families up to and including size four are taken together, there is no evidence that the distribution of the first two children is anything but random. This does not agree with the conclusions of Bernstein ('52), whose data indicated a non-random distribution of the two sexes in the first two children of families of all sizes. However, the calculation of the expectations in that work was based on the binomial distribution, which introduces a source of error because the sex ratios for the first and second children are different and, further, the simple correction for twinning was not made. In any case, the sample size here is about twice as great and should have revealed any tendency for unisexual sibships to occur if they are, in fact, so frequent as to be obvious in smaller samples.

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A DEMOGRAPHIC STUDY OF A DINKA VILLAGE

BY D. F. ROBERTS

Anthropology Laboratory, Department of Human Anatomy, University Museum, Oxford

AMONG the Dinka tribes of the southern Sudan living to the north of Malakal, sometimes referred to collectively by the name Padang, the permanent wet-season villages are nucleated and concentric in pattern. The villages, with their patches of cultivation nearby, are separated from each other by usually a few miles of open grass and occasional scrub. Though infrequent isolated homesteads do occur, the village is the basic territorial and political unit; neighbouring villages are grouped into tribal segments, and several such form a tribe, occupying a continuous territory, whose members formerly united for military purposes in cases of intertribal disputes. The settlement pattern thus differs from that characteristic of other Dinka, amongst whom the homesteads comprising a village are spread out over a large area, while the territorial organization is in essence similar.

Interwoven into this territorial pattern is the clan and lineage system of the northern Dinka. Every man is considered as a member of a lineage tracing descent (though incompletely) from a particular legendary ancestor; these ancestors are regarded as the decendants of others further back in time until the original founder of the tribe is reached. Hence, the various lineages are aranged in groups of increasing inclusiveness from the smallest category specifically named, the *gol*, up to the maximum grouping of the hierarchy, which corresponds to the political entity of the tribe. The diagram (figure 1) illustrates the system as it obtains among the Ageir Dinka. With each *din* a group of villages is associated, each village being primarily the residence of one or more *gols* or sometimes part of a *gol*. This is not to say that all members of a *gol* reside in a particular village, but that the majority

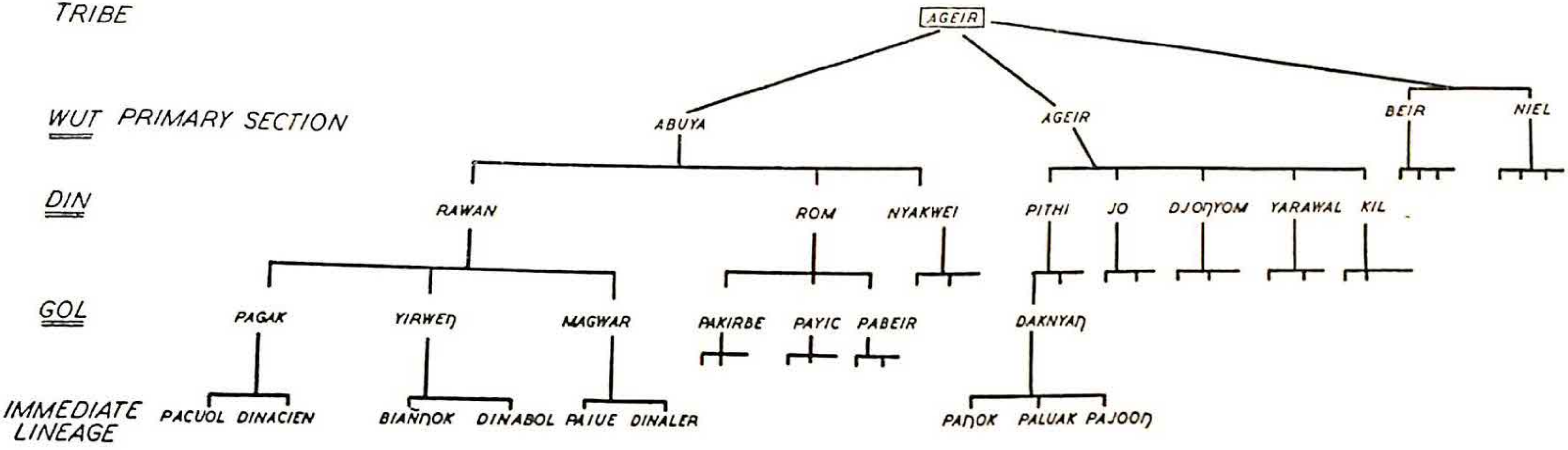
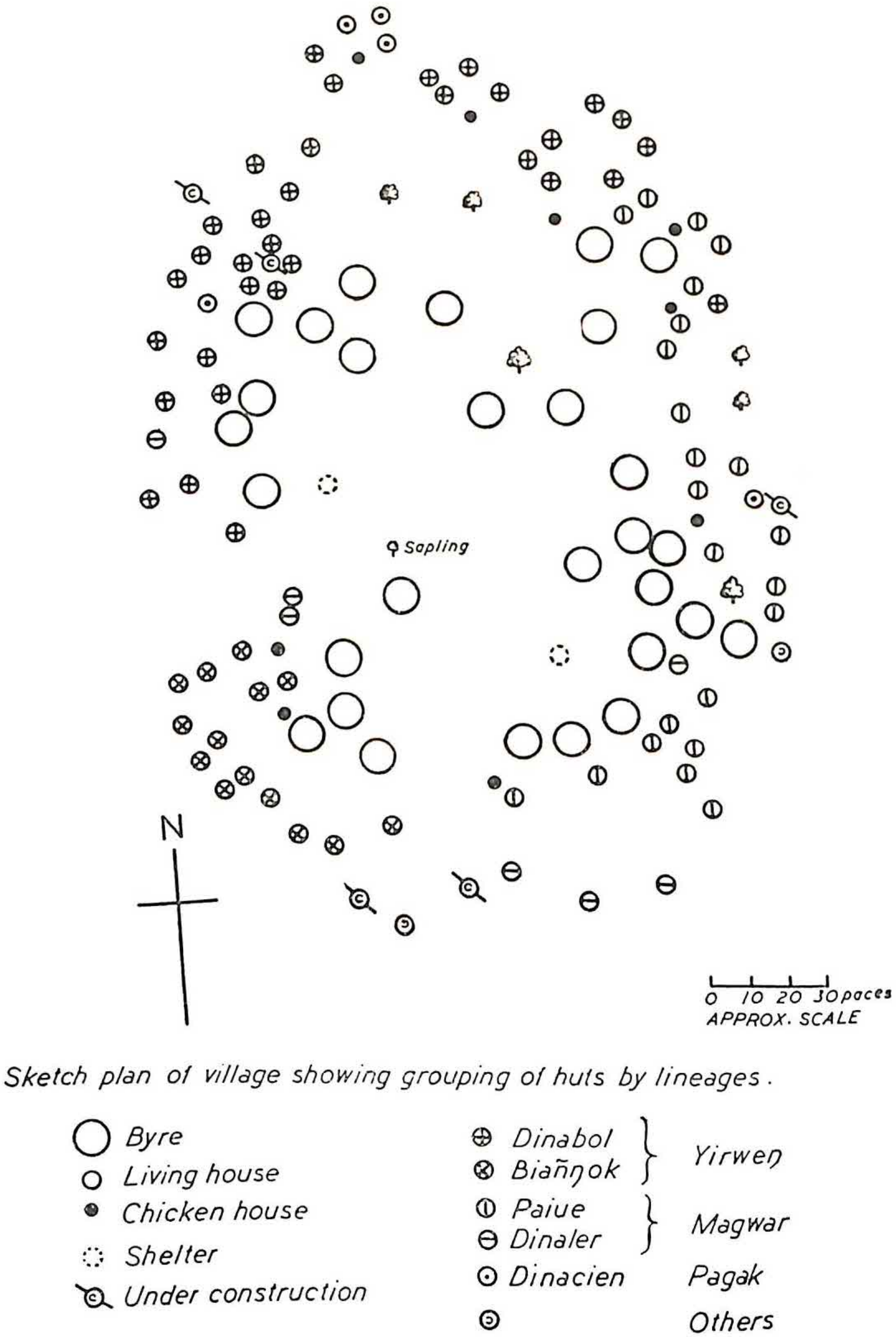


FIG. 1. LINEAGE HIERARCHY OF THE AGEIR DINKA AND ITS GENERAL CORRESPONDENCE TO THE TRIBAL POLITICAL ENTITIES.

of them do. Thus, *gol* Pagak is concentrated primarily at the village Pagwot, *gol* Daknyang at the village of Lek. The lineages play an extremely important part in Dinka life; the personal relationships of individuals, the arrangement of dwelling houses (see figure 2), the grazing of cattle, and numerous other matters are to some extent influenced by the lineage structure. From the demographic point of view, one of its most important functions is in its regulation of the breeding pattern. Marriage is prohibited within the *gol*, but is allowed within the *din* and higher categories, provided that the participants are not closely related on the female side: for example, in *gol* Daknyang a man of the Pangok lineage may not marry the daughter of one of Paluak or Pajoong lineage, but a man of *gol* Pakirbe may marry a girl whose father is of *gol* Payic provided that they are not close relatives on the maternal side.

Of these and the several other modes of social groupings which go to make up the northern Dinka social structure, the village is the most practicable unit for demographic study. Both sexes and all ages are included and, with the existing settlement pattern, there is little difficulty in distinguishing its members. But the wet-season villages are by no means permanent. Apart from the membership changes due to birth and death, newcomers take up residence, established individuals move away—changes which are reflected in the building of new huts and destruction of old ones. Superimposed on these are the regular fluctuations, the seasonal movement of population between village site and dry-season cattle camp, the seasonal influx of Shilluk for grain, and the irregular short-period changes in the actual individuals to be seen in the village due to the veritable stream of visiting that occurs and to the various activities that necessitate an individual's absence from his village. The aim of the present study is to describe the demographic state of a village at a particular time in the hope that some measure of the extent of such fluctuations may eventually be obtained.

The village surveyed, Tir, lies some 100 miles N.E. of Malakal and 21 miles E.N.E. of Melut, latitude 10°32′ N., longitude 32°29′ E. It is a vilage of *din* Rawan of the Abuya section of the Ageir tribe, and is the wet-season residence of two *gols*, Yirweng and Magwar. The following results refer to the demographic situation during the second week of January 1954, shortly before the move to the cattle-camp commenced. At this period the village, of about average size for the Ageir, consisted in its material aspects of 129 buildings, of which 5



Sketch plan of village showing grouping of huts by lineages.

FIG. 2.

Lineages shown are:

for wives, that of the husband;

for women with husbands elsewhere, that of the woman's father;

for widows, that of the late husband or of the woman's father.

were in various stages of construction, and two were destroyed during the week; 29 of these were byres, built as such, two were *geus* or shelters, 9 small huts were used as kitchens, store houses, or quarters for sheep and goats, and there were 84 huts actually lived in by families. The hut plan is given in figure 2. In addition there were a number of less solid structures, chicken houses, granaries, and open folds, not indicated on the plan.

METHOD

To obtain any form of personal information from people such as the Dinka is by no means easy. A Dinka is to some extent distrustful of outsiders, of those of lighter skin colour since the memory of the slave raids in the time of the Mahdiya is still strong, of Europeans from their association with various less pleasant matters such as taxation, injections of cattle and government interference with the established pattern of Dinka behaviour. There is always the possibility of magic in any process not understood—such at least was the very outspoken vehement comment (especially on the part of the women and old men) on the drawing of the hut plan. But the main source of difficulty lies in the extreme independence of spirit of the individual, the product and the basis of the Dinka social pattern wherein self-reliance is at a premium. A Dinka at home will do nothing unless he wants to, or unless the elders of his lineage persuade him.

The use of question and answer on such matters as whether a man has children, the name of his wife or brother, or even quite frequently his own name, may therefore be expected to elicit, in those instances where a complete refusal to respond is not the outcome, frequently fictitious replies or at best partial answers. For the same reasons attempts at enumerating the occupants of huts meet with considerable opposition: nor would a census so conducted provide satisfactory results, for in the huts sleep only small children, unmarried girls, and the women and some of the husbands; older boys and unmarried men sleep in the byres, where are also to be found a proportion of the married men. The dead are not easily spoken of, rendering difficult any discussion of mortality. The only satisfactory method of obtaining demographic data is by direct observation, the basic technique of the field anthropologist who has much to contribute to demographic studies of primitive peoples.

The last was the method employed. The first few weeks of residence in the village were occupied in getting to know the inhabitants by sight and name. Only when all the adults and the majority of the children could be so identified, and the remainder of the children assigned to their respective parents, were the inhabitants listed. Ages of children and about half the adults were estimated from their dental state, supplemented by reference to events remembered and, in the case of the males, to the formal age-set system; from comparison with these individuals, the ages of the remainder could be assessed, supplemented by the evidence of their external appearance. The method is laborious and time-consuming, but the results obtained may be regarded as being as accurate as possible in the circumstances.

RESULTS

The total population of the village at the period of survey was 375 individuals. This figure does not include visitors to the village, but includes those individuals regarded as members of the village who were temporarily absent visiting or on other matters. Expressed on the basis of heads per hut, there were averages of 3.02 individuals per complete structure, and 4.46 per living hut.

TABLE 1

Age structure and ratio of females per 100 males of the population, by assessed age

AGE	TOTAL	MALES	FEMALES	FEMALES PER 100 MALES			
0–4	71	33	38	101.1	98.2		
5–9	53	28	25				
10–14	55	28	27				
15–19	43	23	20			110.8	112.3
20–29	60	29	31		118.5		
30–39	42	18	24				
40–49	27	11	16	121.7			
50–59	15	7	8				
60–69	3	1	2				
70+	6	4	2				
Total	375	182	193			106.0	

The population consisted of 182 males and 193 females, giving an overall ratio of 106.0 females per 100 males. The age-composition is given in table 1, by 5-year age groups for the younger individuals, by

10-year groups for adults. The mean age of the community is 20, less if deaths within age groups are allowed for. Forty-eight per cent of the population is under 15, less than 2% over 65. Table 2 gives the age-structure of sections of the population, of the adult male population as classified by the age-sets, and of the children and unmarried young adults under 20 according to dental state. From the age-structure there is apparent a general tendency for increase of the ratio of females to males with age. For children under 15 years of age it is 101, for sub-adults and adults of 15 and over but under 50 it is 112, for adults of 40 and over it is 122.

TABLE 2

Age structure of sections of the population by objective criteria

MALES BY AGE-SETS

Age set	Age	No. married	No. unmarried
Awaugor	over about 70	4	—
Tilik	over about 60	1	—
Maniel	over about 38	19	—
Ajing	young men	27	26
—	boys	—	105

CHILDREN AND UNMARRIED YOUNG ADULTS (UNDER 20) BY DENTAL STATE

Dental state	Males	Females	Total
Incomplete deciduous dentition	16	18	34
Complete deciduous dentition	20	21	41
Some permanent dentition	39	33	72
Complete permanent dentition except for third molars	34	29	63
Complete permanent dentition	3	2	5

The conjugal condition of the population is shown in table 3. "Those occupied in leviratic unions" refers only to those couples in which the sexual aspects of the levirate (as distinct from the social aspects, the assumption by the male or legal responsibility for his brother's widow) are being realized. The first division of the table gives the present breeding population of the village. In the second division, referring to those who were formerly members of the breeding population, "widowed" is used for want of a better term; the married elder brother of the man in question died without issue, the younger brother (Gor) inherited the wife and of this union a son was born, after which the woman died; Gor therefore is here considered as a former member of the breeding population. Of the widows, at least 8 had lost their husbands within the last three years. Table 4 shows the state of polygamy within the village, but does not include those men who kept one wife in Tir and another elsewhere. Table 5 shows the marital state by age. Whereas two-thirds of the men in their twenties are unmarried, all girls are married by this age, and the figures suggest that the average age of first marriage for men is about 27 and for girls about 18. The percentage of widows to each age-group of the female population increases steadily with age, from 13% at 20–29, 44% at 40–49, to 100% at over 60. Asterisks indicate the situation in the age structure of the males with more than one wife in the village; the restriction of this practice

TABLE 3

Conjugal condition of the population

BREEDING POPULATION	MALES		FEMALES	
Present	Married and those occupied in leviratic unions	47	Married and those occupied in leviratic unions	55
			Married with husbands in other villages	6
Past	Widowers and those "widowed" by decease of leviratic partner	4	Widows	28
			Divorced	1
Unmarried		131		103
Total		182		193

TABLE 4

Polygamy state

Married men with 1 wife in the village	40
Married men with 2 wives in the village	6
Married men with 3 wives in the village	1

TABLE 5

Conjugal condition by age

	MALE			FEMALE				
	Unmarried	Married	Widowed	Unmarried	Married	Widowed	Divorced	Widowed as percentage of all women
Under 15	89	—	—	90	—	—	—	—
15–19	23	—	—	13	7	—	—	—
20–29	19	9	1	—	26	4	1	12.9
30–39	—	16	2	—	18	6	—	25.0
40–49	—	11 *	—	—	9	7	—	43.8
50–59	—	7 ***	—	—	1	7	—	87.5
60–69	—	1	—	—	—	2	—	100.
70+	—	3 ***	1	—	—	2	—	100.
	131	47	4	103	61	28	1	

* Indicates the individuals with more than one wife in the village.

to the older age-groups is obvious. Some others of the middle-aged men are also polygamous, their second wife living elsewhere; this distribution of wives accounts for 5 of the 6 women in table 3 whose husbands live in other villages (the sixth woman was newly married and had not yet gone to her husband's village).

The extent of the network of the marital links between Tir and other Dinka villages is shown in table 6 for a sample representing

TABLE 6

Marriage pattern observed in the village, by birthplace and clan of the spouses, of the present generation compared with that of the previous generation

MARRIAGES	PRESENT GENERATION	PREVIOUS GENERATION
Within Tir	3	3
Tir with Pagwot	3	2
Within *din* Rawan	6	5
Tir with Rom villages	7	0
Tir with Nyakwei villages	1	2
Between *dins* within *wut* Abuya	8	2
Total within *wut* Abuya	14	7
Tir with Ageir villages	16	12
Tir with Niel villages	8	0
Tir with Beir villages	2	1
Pagwot with Ageir and Niel villages *	2	1
Between *wuts* within tribe Ageir	28	14
Total within tribe Ageir	42	21
Tir with villages of tribe Dunjol	2	0
Tir with villages of tribe Abialang	6	6
Tribe Ageir with villages of tribe Abialang *	1	1
Between tribes of Padang Dinka	9	7
Total within Padang Dinka	51	28
Tir with other Dinka tribes	0	0
Tir with Nuer	0	2
Total sample	51	30

* Resident in Tir.

existing unions and survivors of unions; to these the column "present generation" refers, while the column "previous generation" refers to informants' parents now deceased. Numbers are too few for any significance to be attached to the individual entries, but the totals "within *wut* Abuya," "within tribe Ageir" and "within Padang Dinka," show that there has been little change in the marriage pattern between the two generations. Table 7 compares these totals for the present generation of Tir with those obtained for a sample of 59 present generation matings noted in other villages of each of the four sections of tribe Ageir. The marriage pattern is very similar in the two samples, and Tir appears to be representative of the Ageir in this respect.

TABLE 7

Marriage pattern of Tir compared with that of other Ageir Dinka—present generation

	TIR	OTHER AGEIR DINKA
Total within *din*	6	5
Total within *wut*	14	15
Total within tribe	42	46
Total within Padang Dinka	51	58
Padang Dinka with other Dinka	—	—
Padang Dinka with other peoples	—	1
Total sample	51	59

Data relating to reproduction are given in tables 8-11. That fertility

TABLE 8

Fertility ratio (children under five per 100 women aged 15-49) compared with ratios for some other populations

Tir	78.0
Algeria Moslems (1948)[1]	63.1
United States (1950)[1]	42.3
Hutterites (1948)[2]	96.9
Papago (1952)[3]	51.7

[1] United Nations Demographic Yearbook ('51)

[2] Eaton and Mayer ('53)

[3] Jones ('53)

TABLE 9

Offspring per female member of breeding population, present and past, by age-groups

MATERNAL AGE	NO. OF FEMALES	AVERAGE NO. OF SURVIVING OFFSPRING	AVERAGE NO. OF OFFSPRING REMAINING IN VILLAGE
15–19	7	.14	.14
20–29	31	1.94	1.94
30–39	24	3.79	3.50
40–49	16	3.69 *	3.44
50–59	8	2.38 *	1.88
60+	4	2.25 *	2.00

* These figures are probably underestimates on account of omission of some of the offspring married away from Tir.

TABLE 10

Number of live births per woman

	NO. OF MOTHERS	TOTAL NO. OF LIVE BIRTHS	AVERAGE NO. OF LIVE BIRTHS
Number of live births for 8 women aged 40–50	8	43	5.38
Number of sibs remembered by 20 males whose mothers attained late adulthood	20	101	5.05
Total	28	144	5.14

TABLE 11

Surviving family size *

NUMBER OF OFFSPRING SURVIVING	NUMBER OF WOMEN
0	11
1	16
2	9
3	21
4	23
5	9
6	1

* Some offspring married away from Tir may have been omitted from this table.

is high but not unusually so is shown by the fertility ratios in table 8. Of the married women without children, there was only one woman who was not described as newly married; she was divorced. There were two pairs of twins among the children under 15, giving a rate of multiple births (assuming no differential mortality) of 1 in 88.5. Table 9 provides satisfactory fertility information only for the first three age-groups, as at maternal ages of 40 and above the number of offspring married away from Tir increases. While both these tables represent surviving offspring, table 10 records the numbers of live births for a small sample of women who have almost or actually attained the end of their reproductive span; the last may be less reliable, since the information was obtained during discussions with individuals, with the attendant risks of concealment and forgetfulness on the part of the informants. However, the two estimates, one of children born and the other of brothers and sisters remembered, are very close. Table 11 is of interest, despite its deficiency in reliability on account of the probable omission of some offspring married away from Tir, on several counts. It demonstrates the rarity of occurrence of a woman with more than 5 children surviving; a fairly high modal family size; and a low incidence of small families—such as there are include one widow of over 60 with no surviving children, and 5 women over 45 with but one surviving child each.

TABLE 12

Child mortality in a sample of 34 women

MATERNAL AGE	NO. OF WOMEN	TOTAL CHILDREN BORN	NO. SURVIVING	NO. DEAD	DEAD AS % OF TOTAL
15–19	3	1	1	0	0
20–29	12	26	25	1	3.8
30–39	11	49	42	7	14.3
40–49	8	43	30	13	30.2

The information concerning mortality given in tables 12 and 13 was, like table 10, again derived from questioning, and may again be biased. However, in the majority of instances answers were checked and rechecked against those obtained on other occasions and from relatives of the informants. Error, in that the number of children born (table 12) and the number of sibs who reached adulthood (table 13) may be underestimated, is in one direction, and accordingly the final columns of both tables are to be regarded as minimal estimates.

TABLE 13

Adult mortality as estimated from a sample of 19 individuals

INFORMANT'S AGE	NO. OF INFORMANTS	TOTAL NUMBER OF SIBS WHO HAVE REACHED ADULTHOOD (INCLUDING INFORMANT)	NO. OF ADULTS SURVIVING (INCLUDING INFORMANT)	NO. OF SIBS DYING AFTER REACHING ADULTHOOD	% OF SIBS DYING AFTER REACHING ADULTHOOD
20–29	5	16	14	2	12.5
30–39	7	29	23	6	20.7
40–49	7	31	17	14	45.2
50–59	2	11	6	5	45.5

TABLE 14

Effective population size, variance of random genetic drift, admixture rate, and average inbreeding coefficient in the village, primary section, and tribe

	TIR	ABUYA SECTION	AGEIR TRIBE
Total population	375	1300	13400
Effective population size (N_e)	109	380	3913
Random drift per generation (σ^2_{dq}) (where $q = .5$)	.001146	.0003292	.00003195
Admixture rate (m)	.50	.35	.11
$N_e m$	55	133	430
Average inbreeding coefficient (F)	.00153	.00096	.00049

DISCUSSION

The demographic pattern.

In 1955 the first attempt at a census in the Sudan was made with results yet unpublished, and there is little other demographic information available for comparative purposes. Such comparisons with other African data as are made during the course of this discussion are for purposes of illustration only and are not intended to be comprehensive. Further African data will be found in Kuczynski's compilations. In situations where direct census is difficult, an indirect method such as estimation from the number of huts may give a more reliable indication of the size of the total population. Provided that a series of samples, such as the present, is available to enable the estimate to be made there seems no reason why a tribal count should not be obtained even from air photographs. The second figure given (heads per living hut) would be more useful for such an estimate, since the number of individuals per complete structure is affected by the cattle wealth of the population. The average of 4.46 observed here should not necessarily be taken as indicating overcrowded unhealthy conditions; the greater part of the daytime life is lived out of doors, and at night the older boys and some of the married men sleep in the byres, while older children in a large family may sleep in other huts with relatives and friends. The interiors of the huts are clean and sufficiently spacious for their purpose, and there is many a civilized family in urban Britain with more cramped and less healthy sleeping quarters.

The village is small, and accordingly too much stress should not be laid on the individual figures, but rather on the general trends they demonstrate.

Although the total ratio of females per 100 males of the village is rather high by comparison with the tribal ratios from 1948 census data of southern Nilotes (Kenya Luo 101.4, Uganda Lango and Acholi respectively 101.8 and 102.6), it is by no means an improbable figure; for instance the provisional ratio in England and Wales at the 1951 census was 108.1. Increase of the ratio of females to males with age is a normal phenomenon, reflecting the more hazardous pursuits of the male sex.

The ages of individuals are of course estimates, and the possibility of some error should not be overlooked. Nevertheless there is no doubt of the agedness of the eldest individuals. Abukjok and Nyikang, members of Awaugor age-set, were adult men at the time of the Mahdiya, which, since the battle of Omdurman occurred in 1898, makes them at least 70 years of age; Akok, a member of Maniel age-set, was brought to Tir by his father at that time, which makes him at least 55. The age structure of the village demonstrates either that the community is expanding, or that there is high mortality throughout the population amounting to a steady loss of one-third of the population in each 10-year age-group; that is to say that of every 45 individuals who are now 20 years old, only 30 will attain the age of 30 years, and of these only 20 will reach the age of 40 years. The age-sets in table 2 vary in chronological length; the appropriate ritual authority decides when it is time to cut the age-set and inaugurate a new one, and a change of set also occurs at his death. Since a young man takes the name of the set when he proves himself worthy (formerly in the fight, today by killing a wild animal in the hunt), no lower age limit can be given; several boys of 17 and 18 were already included.

The sex difference in average age of marriage, deduced from table 5, is of interest. A number of men marry later in life than they wish because of the need to obtain cattle for the bridewealth and because marriage of brothers occurs in strict order of age. A third son, for example, has to wait until sufficient cattle have been accumulated to marry off his two elder brothers before his own claims may be considered, no matter how hard he works in the meanwhile. The most striking aspect of the demographic situation is the high proportion of widows. Considerable attention was given to these individuals as soon as it was realized that their number was large, and there is no doubt that those recorded as widows were indeed truly so. The 8 recently widowed referred to above were all under 40, and some at least of these younger widows would subsequently come to be leviratically "occupied" sexually, and so re-enter the breeding population. Some of the older ones had indeed produced children to the husband by his kin after his death, but were no longer thus leviratically "occupied." Whether such a high excess of widows is usual or not is difficult to determine. The actual number is similar to the number of unmarried men between the mean ages of marriage of male and female,—in other words, given such a mortality pattern with such sex and polygamy ratios, the difference in mean age of marriage between the sexes may be expected to lead to the regular occurrence of this proportion of widows. On the other hand, the phenomenon may be of a temporary nature on account of some temporary elevation of the relative number of females. In the two preceding years Tir had been involved in serious kala azar epidemics which swept the area; the village could almost be described as being in a condition equivalent to mourning, for no adult dances were being held on account of the many deaths that had occurred; and it may be, though there is yet little evidence for it, that there is differential mortality between the sexes in kala azar. Alternatively, some males may have left the village, for example, for work or to settle.

Mortality is high by European standards. The age-structure suggests, if the population size be static, that there is a steady loss of about one-third of the existing population every 10 years. The information on child mortality (table 12) gives a slightly lower but compatible estimate; the estimate of adult mortality (table 13) is rather lower, though the weaknesses of the data in these two tables should be remembered in making the comparison. It appears that by the time the average woman is 50, she has lost at least one-third of her children, and about a half of those among her brothers and sisters who succeeded in reaching adulthood, besides those who died before doing so; she has also very probably lost her husband. Whereas a widower at this age would take another wife, to a widow would be left only the prospect of increasing loneliness, were it not for the close-knit ties of kinship and the practice of living by the side of relatives. She still has a function to perform in the community; she will assist her surviving daughters to rear their families, some of her grandchildren will sleep in her hut—she may at this age find herself with another family to rear, that of a deceased daughter; and, using her tongue to good advantage, she will restrain the younger members of the community from straying from the established path of customary procedure.

By African tribal standards, however, the mortality is less depressing. It appears to be lighter than in a Nyasaland Bantu sample (Atonga), where 156 women under 25 are reported as having lost 26% of their children, 201 women of 25-35 had lost 39%, and 115 women over 35 had lost 54% (Nyasaland Medical Report, '36). Another Nyasaland general sample of 2,159 wives "not likely to have any further children but . . . not so old as to have forgotten the details" had lost 44% of their offspring (Nyasaland Census Report, '26). A sample from Kiberege, Tanganyika, showed that women aged 30–50 had lost 52.8% of their children, and women over 50, 53.5% (Culwick and Culwick, '39). In the Sudan, for 67 Azande women past childbearing only 70% of their children had reached adulthood or were still surviving, 94 women aged over 30 but who had not yet reached menopause had lost 32%, and 87 under 30 had lost 22%; 39 Balanda women of the second age-group had lost 22% and 40 women under 30 had lost 30% (Culwick, '50). In East Africa, Richards and Reining ('54) noted child mortality (0–15 years) at 33.5% and 27.9% respectively among the Haya and Baganda. From this brief comparison with some of the limited data available for Africans, it appears that although the incidence of deaths among offspring reported by older women in several samples is not dissimilar to that among the

Dinka, child mortality reported by the younger maternal age-groups is less severe among the Dinka. If this is indeed so, a contributory explanation should perhaps be sought in such phenomena as the communal obligations to supply milk to neighbours with children but with no lactating cows, and to lend a cow to kin in such a position; and to the way in which children receive preference in the allocation of some foods, especially milk and eggs.

The evidence regarding fertility is, like the mortality data, indirect, but some indication may be obtained from tables 8–11. The frequency of multiple births appears to be similar to that found in Europeans, and much lower than the average of 1 in 51 obtained by Jeffreys ('53) in his survey of African twin data. Comparison is not straightforward, since the incidence of multiple births is usually referred to the actual number of births, whereas the Dinka figure relates the survivors of twin births to those of single births. Since heavier mortality may be associated with multiple births, the Dinka figure is not incompatible with Jeffreys' estimate. On the other hand, Jeffreys based his estimate largely on hospital records; it may be that in the small percentage of African births which occur in hospitals a larger proportion of the more difficult cases are represented, while less difficult births may be completed at home, so that the general average of 1 in 51 is possibly an overestimate.

High fertility is frequently regarded as a characteristic of primitive populations, though over 30 years ago Carr-Saunders pointed out that family size in fact tended to be small in primitive human groups. While the samples from which table 10 is compiled are small and the information may possibly be biased, the average of 5.1 live births per woman during her reproductive period indicates that fertility is fairly but not excessively high and certainly does not approach the biological limits; compare for instance the average of 10.3 for Hutterite women in the United States (Eaton and Mayer, '53). The Dinka average accords well with other African data. In a sample of 134 Basuto women married more than 16 years an average of 5.60 live offspring per head was obtained (Basutoland Medical Report, '26). In Nyasaland 21 samples of women past childbearing gave averages varying from 4.6 to 8.0, with a general average for the whole 2,159 women of 5.64 (Nyasaland Census Report, '26). The average number of live births per head in a Bechuana sample of 593 women over 50 was 5.4 (Schapera, '54), the same figure as that reported for a smaller sample of 184 Kgatla women past the menopause (Schapera, '39). A small Sukuma sample of 39 women married more than 15 years had produced an average of 4.7 offspring (Tanner, '54), while the average for Haya and Baganda women over 45 lies between 4 and 5 (Richards and Reining, '54). Zande women past childbearing, 67 in number, gave an average of 5.6 live births per head, while 17 Balanda averaged 5.0 births (Culwick, '50). The Dinka average is markedly affected by the spacing of children, regarded as socially desirable. The spacing benefits the health of the mother, while the fact that all women are married and a very high proportion of them produce children (perhaps the main aim of Dinka marriage) means that the burden of ensuring the biological continuity of the community is spread as widely as possible.

The other evidence regarding fertility presented in tables 8, 9, and 11 refers to surviving offspring, and hence is the outcome of the balance between fertility and mortality. The fertility ratio, despite its statistical shortcomings, again demonstrates that fertility is fairly high. The average number of offspring per woman by maternal age-groups (table 9) throws some light on the spacing of births, and makes interesting comparison with some other African samples, though differences in methods of age assessment should be remembered. In the Basuto sample 210 women married less than 8 years had produced an average of 1.43 offspring, while 175 women married 8–16 years had produced 3.33 (Basutoland Medical Report, '26). Kavirondo women, 2,591 in number, with a mean age of about 26 had produced an average of 3.03 offspring (Kenya Medical Report, '22). Atonga women under 20 had produced 1.61 children, those aged 20–25 averaged 2.44, those aged 25–35 averaged 3.99 (Nyasaland Medical Report, '36). Kiberege women under 20 averaged 0.92 births, those aged 20–30, 1.99 and those aged 30–50, 2.49 offspring (Culwick and Culwick, '38). Haya and Baganda women aged 35–44 averaged respectively 2.8 and 3.8 live births (Richards and Reining, '54). Azande and Balanda women under 30 averaged respectively 0.9 and 1.7 births, while those over 30 but still capable of reproducing averaged 2.2 and 4.6 births (Culwick, '50). When the lower age-groups of the Dinka sample are adjusted for mortality (by means of table 12), the distribution of births appears to be similar to that found among the Basuto; the youngest Dinka wives are not overburdened with too many births as compared, for instance, with the Atonga and Kiberege samples, while the Dinka women aged 30–50 are clearly distinguished by their greater number of offspring from the samples of Kiberege, Haya, Baganda, and Azande.

Whether the population is numerically static is difficult to decide.

Four lines of evidence may be compared, namely the age structure of the village (table 1), the number of live births per woman (table 10), the offspring per female by maternal age-groups (table 9) and the mortality data (tables 12 and 13). The age structure of the village suggests that either the population is stable with a heavy mortality, or that mortality is lower and the population expanding; the maximum mortality would represent a loss of about one-third every 10 years, which would require, to maintain a numerically stable population, rather less than 3 births per breeding woman every 10 years. Such a reproductive rate is compatible with the evidence in tables 9 and 10. However, the information relating to child deaths suggests a slightly lower wastage, and that for adult deaths indicates a rather lower mortality; it may therefore be concluded that the population is in fact expanding.

Here then is the general demographic pattern to be perceived in this Dinka village: a low average age, a high proportion of children, arising from a fairly high fertility and a conjugal situation in which all women (and all men after a somewhat later age) are married and very few fail to reproduce. Reproduction of the community is shared by the maximum number of women and is spread over the whole of their reproductive span. Some polygamy and the practice of the levirate offset to some extent the fairly high ratio of females to males, but not sufficiently so as to absorb the high proportion of widows, a likely result of the age difference between the sexes at time of marriage. Mortality is fairly high, though not excessive by African tribal standards, and its failure to balance the fertility results in a situation of population increase.

Some Genetic Considerations.

From the data given in tables 6 and 7 concerning the marriage pattern, some attempt can be made to assess the extent of the biological intrabreeding population, *i. e.*, that group within which most of potential matings are to be found (as distinct from the demographic breeding population of the village—those individuals who are rearing children and from whom in their present conjugal state further offspring are possible). The breeding 'isolate' is not the village, nor the *din*, nor the tribal section, since 94%, 90%, and 74% respectively of marriages occur outside these units. Nor does it appear to be the tribe (with 20% outside matings); the location of Tir not far from the geographical center of the Ageir tribe should be remembered in this context, for the percentage of outside matings may perhaps be higher in the peripheral settlements of the tribe. It may well be the Padang Dinka as a whole, a unit comprising some 30,000 individuals (estimates quoted by Bryan and Tucker, '48), for in the intertribal marriages few spouses came from the more proximate sections of the adjacent tribe. The absence of marriages with Shilluk, geographically quite close to the settlements sampled, reflects perhaps the importance of the linguistic barrier between the peoples, a preference in the present Dinka generation in forging links with other Dinka who possess common values, and the fact that the prestige of a woman is measured in terms of her bridewealth, which among the Shilluk is usually 10 head of cattle while among the Ageir it is usually 20; this is not to say that unions of Dinka/Shilluk do not occur, but they seem to be more frequent in Shilluk villages.

Within the biological population of the Padang Dinka, if such it be, the extent of the territory occupied prevents the realization of panmictic mating over the whole area, as table 7 shows; a young man finds his wife-to-be by attending dances in other villages; and there is in practice some limit to the range he covers in so doing. Acting in the opposite direction, however, is the influence of the lineage system; the territorial localization of clans and lineages, with the prohibition on marriage within the *gol* and between individuals related on the distaff side, tends to direct mating further afield and away from the localities of the father's and mother's relations. The lineage system seems to suggest that the population is characterized by outbreeding. Occasionally a widow is leviratically occupied by the son of her husband by another wife, though such a situation is infrequent enough to affect hardly at all the general outbreeding pattern. For many, however, the lineage is frequently not a true record of paternal descent, but is merely a convenient subdivision of the community—a peg on which to hang one's activities and behaviour, so that outbreeding is perhaps less than might at first seem and the mating situation may not be far from random. Certainly for those blood groups where the heterozygote is phenotypically discernible there seems to be no increase of heterozygosity over that expected (Roberts, Ikin, and Mourant, '55), though the sample is too small for this finding to be stressed. Average inbreeding coefficients for the population are given in table 14; these estimates are to be regarded as maximal since they are calculated on the assumption of random mating.

The smaller the social unit, the greater is the frequency of marriages with outside units. The way in which this balance renders unlikely any important random genetic drift may be illustrated if the demographic data from Tir are applied to the mating results obtained from the general sample of Ageir Dinka, in a similar manner to Lasker's ('52) Mexican study.

Random drift in a population per generation may be calculated as follows (Wright, '40 and elsewhere):

$$\sigma^2_{dq} = \frac{q(1-q)}{2N_e}$$

where σ^2_{dq} is the variance due to drift, q represents the gene frequency and N_e the effective population size. The effective population size (for a static population) is obtained:

$$N_e = \frac{2N(N-1)}{(N-1)\sigma^2_k + 2N} \text{ usually rounded to } \frac{4N-2}{\sigma^2_k + 2}$$

where N is the number of parents in the population and σ^2_k is the variance in the number of gametes contributed to the next generation (Wright, '38 and personal communication). The effect of unequal numbers of male and female parents on the effective population size only becomes important if the inequality is extreme. In successive generations the variance is compounded, so that in generation g the variance $(\sigma^2_q)_g$ is $q(1-q)[1-(1-\frac{1}{2N_e})^g]$ (Wright, '42).

Suppose the Padang Dinka were composed of a large number of local populations, each completely isolated from the others, of the same effective size as Tir. For Tir, the number of adults is 170, of whom the number married is 140, and the number of parents (N) is 124. The average family size* is 2.70 (table 11) with variance (σ^2_k) 2.53, giving an effective population size (N_e) of 109. For each such local population,

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* Here the gametic contribution by the parental population to the next generation (not easy to define on account of the overlapping of generations) is reckoned in terms of that of all the female parents of the village. That its mean and variance may actually be higher were all parents considered is shown by comparison of the actual contributions of the two sexes in those families where both parents remain alive and in the village:

		Gametic contribution to the surviving filial generation	
	No.	Mean	Variance
Males	45	2.98	4.61
Females	53	2.45	2.90

The relatively slight degree of polygamy found in this village clearly has a quite marked effect on the gametic contribution.

random drift per generation in the case of an initial gene frequency of 0.5 would be (σ^2_{dq}) .001146; the chances are therefore one in 50 that the gene frequency would change by more than ± .079 (*i.e.*, $\pm 2.33\sigma$) in the subsequent generation, should there be no mutation, selection, or intermixture. Should the population remain completely isolated, by the 30th generation the accumulated variance [$(\sigma^2_q)_g = .032$] would be such that there is about one chance in 200 that an initial gene frequency of .5 would become 0 or 1. In other words, in an isolated population of this effective size, drift would be likely to have an important effect on the gene frequencies.

Suppose, however, that such hypothetical isolated local populations were comparable in numbers with (a) the Abuya section and (b) the Ageir tribe, whose total numbers are estimated by Bryan and Tucker as 1300 and 13400 respectively. Applying the demographic data for Tir to these units, the effective population size, as shown in table 14, for *wut* Abuya is 380 and for tribe Ageir 3913. Random drift per generation (σ^2_{dq}) and the accumulated variance [$(\sigma^2_q)_g$] are considerably smaller, so that whereas for units the size of Tir the loss or fixation of a gene of initial frequency .5 attains the probability of one in 200 after 30 generations, this probability is only reached after about 100 generations for units the size of *wut* Abuya, and after about 1200 generations for units the size of tribe Ageir.

For isolated populations the size of the Ageir tribe random genetic drift is not likely to lead to rapid differentiation, though its effect would be more likely in populations the size of the Abuya section, and important in populations the size of Tir. In the Dinka, however, the units are by no means isolated. In 51 marriages in Tir, in three instances both spouses were from outside the village, and in 45 instances one spouse was born outside the village, giving an admixture rate of 50%. From villages of the Abuya section details of 77 present generation marriages were recorded; in 24 instances both spouses came from within the *wut*, in 52 one spouse was from outside the *wut*, and in one case both partners were incomers, giving an admixture rate of 35%. For 110 matings recorded in villages of tribe Ageir, in 20 cases one partner was from outside the tribe, and in two instances both spouses, the admixture rates being 11%.

Wright ('40, '43) has shown that differentiation due to drift, for a given gene frequency, depends upon the product of the effective population size and the migration rate ($N_e m$, where m is the effective proportion of a population replaced in each generation by migrants). For a gene frequency in the total poplation of .5, there is very great differentiation of local gene frequencies where $N_e m$ is less than 0.5; there is important differentiation where $N_e m$ is less than 5, but differentiation is slight if $N_e m$ is greater than 50. With the migration rates found for the village, section, and tribal units, it is clear that differentiation is slight in each ($N_e m$ being approximately 55, 133 and 430 respectively). Were the tribal section to be characterized by the migration rate found for the tribe, or the village by the rate found for the section, random drift would be more marked ($N_e m$ respectively 42 and 38), and still more pronounced in village units were these to have a migation rate as low as that found for the tribe ($N_e m = 12$).

These calculations are at best estimates—for instance, village demography may not in fact be representative of the tribal situation, and some adjustment should be made for the deduced expansion of the population—but they are considered to be sufficiently accurate to allow the general conclusion that, in the present generation of Dinka, the effect of random genetic drift on gene frequencies is not pronounced, whatever the population grouping taken as the unit.

The mortality estimates, whether from the age structure or from the results of questioning, suggest that a large proportion of individuals born fail to attain adulthood—perhaps as much as 50%. Moreover, mortality between adulthood and the end of the reproductive period is high—again perhaps as much as 50%. So that not only is there a large proportion of individuals born who fail to contribute genetically to the next generation, but of those who do reproduce some have a longer period for so doing than others, which on acount of the spacing of births results in a differential contribution to the next generation. It is under these demographic conditions that the effectiveness of natural selection in man can be fully appreciated.

Speculations on Demography and Social Institutions.

It is in its demographic context that one function of the age-set system in a politically diffuse people such as the Dinka may perhaps be appreciated. Seligman regarded their age-set system as essentially of a military nature; in battle, however, it appears that grouping was usually on the basis of lineages and sections, and there would accordingly seem little reason to regard the Dinka age-sets as military units. Among the Dinka political action is taken after discussion among the elders; government is by the experience of the elders; the older they are the more experience they have, and for the efficient functioning of the community experience is desirable. But the demographic pattern suggests that there is little chance of an individual achieving a ripe old age. It is therefore necessary to preserve those who are elderly and ensure some veneration for them. This the practices associated with the age-set system appear to achieve, *e. g.*, the prohibition against fighting with a member of a senior age-set of the community, the eating and placing separately at feasts, the preferential allocation of parts of a sacrificed animal to the old.

Excess of adult females over males calls for polygamy or promiscuity to utilize the full female reproductive potential, so necessary where mortality is high. Promiscuity as a regular mating pattern occurs in no known human society (Lowie, '48), and indeed may well be incompatible with the functioning of a human society, so that polygamy is the usual response to such a sex ratio in such a demographic situation. But marriage is more than a mating contract and is insured by the payment of bridewealth, which among the Dinka here discussed leads to later marriage for males—a delay which in no way impairs their capacity to reproduce, though it does somewhat reduce the number reproducing, and diminishes the period over which each may contribute to the next generation. This delay benefits the cattle wealth of the community, since it is affected by the sex-ratio—fewer men than girls to be married means that fewer cattle have to be paid away than are received. The mortality pattern, with this age difference between the sexes at marriage, creates a number of widows before the end of the reproductive period. Socially, remarriage for them would be very difficult to arrange. For the utilization of the remainder of their reproductive potential the importance of the levirate is obvious.

There are numerous other instances in which the influence of demography may be detected in social institutions, and from the preceding discussion the extent of the influence of the social on the demographic pattern is readily discernible. The two seem to be intimately related. The need to include demographic considerations in attempts to understand the functions of a particular institution in a society is clear.

SUMMARY

The demography of a Dinka village in a given week early in 1954 is analysed. The main features are a low average age, a high proportion

of children, and a conjugal situation in which all women (and all men after a rather later age), are married, and very few of these fail to reproduce. Reproduction of the community is shared by the maximum number of women and is spread over the whole of their reproductive span, fertility being fairly high but not excessively so. There is a fairly high ratio of females to males. Polygamy and the practice of the levirate are not sufficiently extensive to absorb the high proportion of widows, which may be a result of the age difference between the sexes in the time of marriage. Mortality is fairly high, though not excessive by African tribal standards, and the population seems to be increasing.

The genetic implications of the demographic pattern are discussed. The possibility of genetic drift occurring in any unit, from the village to the total intrabreeding population estimated at 30,000 individuals, is shown by examination of the mating pattern to be remote, while the demographic situation is such as would be conducive to the operation of natural selection. Reference is made to the close relationship between demography and social institutions.

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MIGRATION AND MENTAL DISEASE IN NEW YORK STATE, 1939–1941

BY BENJAMIN MALZBERG

New York State Department of Mental Hygiene

THIS is a study of migration in relation to mental disease, as measured by differential rates of first admissions to hospitals for mental disease in New York State. For the purpose of this analysis, a migrant is defined as a resident of New York State who was born in the United States, but outside of New York State. This is not the most desirable definition of a migrant, because it includes persons born just beyond the borders of New York State (*i. e.*, Connecticut and New Jersey), but excludes many who, though born in New York State, may have moved several hundred miles within the State. It also excludes many natives of New York State who may have moved great distances about the country, ending by returning to New York. However, data based upon this definition do afford a useful approximation to the study of migration, and are of especial value because they are available for first admissions to mental hospitals and also for the general population, and thus permit the computation of rates.

Using this definition of migration, Malzberg ('36) made an analysis of native white first admissions to all mental hospitals in New York State during the three consecutive fiscal years which ended June 30, 1931. They were divided into two groups—those born in New York State, and those born elsewhere in the United States. The latter constituted the migrant group. It was then shown that white migrants had an average annual rate of first admissions of 156.9 per 100,000 migrant population, compared with a rate of only 44.6 for the indigenous group. The rates for the migrant group were similarly in great excess for each of the numerically important groups of mental disorders. There are no statistics of the age distribution of the migrating and indigenous populations of New York State, as defined above. It is known, however, that migrating populations include an excess of adolescents and young adults (Thomas, '38). This would tend to reduce the rate of first admissions among the migrant population. Despite this selective factor, the rate for white migrants was so greatly in excess over that for the indigenous population that the difference must be considered significant. We shall assume that statistics of hospitalization are an adequate measure of the relative incidence of mental disease in New York State (Malzberg, '55).

Similar results were found for native Negroes for the three years ended June 30, 1931 by Malzberg ('36). The Negro population born in New York had an average annual rate of first admissions to all hospitals for mental disease of 40.0 per 100,000 corresponding population, whereas the Negro population living in New York but born elsewhere in the United States had a rate of 186.2. The rate for each major group of mental disorders was similarly higher for the migrants.

It is now proposed to repeat these investigations, using the statistics of first admissions to all hospitals for mental disease in New York State during the three fiscal years ended June 30, 1941. During this period there were 27,530 native white first admissions. Of this total, 20,838, or 75.7%, were born in New York State, and 6,692, or 24.3%, were born elsewhere in the United States. Those born in New York State had an average annual rate of first admissions of 80.8 per 100,000 population. Migrants had a corresponding rate of 169.6. The latter rate was in excess by 110%.

The relative distribution of the major groups of mental disorders is shown in table 1. The classification is that adopted by the American Psychiatric Association in 1934. The classification is still the official classification employed by the New York State Department of Mental Hygiene. Of the 20,838 first admissions who were born in New York State, 5,763, or 27.7%, were diagnosed as dementia praecox. The next largest group, psychoses with cerebral arteriosclerosis, included 3,010, or 14.4% of the total. The other groups were of lower order, the largest being senile psychoses and manic-depressive psychoses, each including 8.9% of the total.

The corresponding distribution for the migrating first admissions did not differ greatly from that for the indigenous group. Dementia praecox included 25.6% of the total first admissions, followed by psychoses with cerebral arteriosclerosis, with 12.7%.

Differences between the two groups of first admissions with respect to age were not too great. (See tables 2, 3) Thus, the average ages for

TABLE 1

Native White first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to mental disorders, and place of birth

	BORN IN NEW YORK STATE				BORN IN UNITED STATES, EXCLUDING NEW YORK STATE			
			Total				Total	
MENTAL DISORDERS	Males	Females	Number	%	Males	Females	Number	%
General paresis	630	257	887	4.3	308	128	436	6.5
Alcoholic	1,046	182	1,228	5.9	491	87	578	8.6
With cerebral arteriosclerosis	1,597	1,413	3,010	14.4	456	395	851	12.7
Senile	791	1,056	1,847	8.9	160	301	461	6.9
Involutional	379	817	1,196	5.7	95	212	307	4.6
Manic-depressive	600	1,251	1,851	8.9	190	414	604	9.0
Dementia praecox	3,028	2,735	5,763	27.7	834	880	1,714	25.6
Other	2,806	2,250	5,056	24.3	988	753	1,741	26.0
Total	10,877	9,961	20,838	100.0	3,522	3,170	6,692	100.0

TABLE 2

White first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to age and place of birth

	BORN IN NEW YORK STATE				BORN IN UNITED STATES, EXCLUDING NEW YORK STATE			
			Total				Total	
AGE (YEARS)	Males	Females	Number	%	Males	Females	Number	%
Under 15	222	107	329	1.6	24	12	36	0.5
15–19	700	594	1,294	6.2	148	111	259	3.9
20–24	1,155	956	2,111	10.1	271	251	522	7.8
25–29	1,068	1,094	2,162	10.4	348	364	712	10.6
30–34	1,065	995	2,060	9.9	397	344	741	11.1
35–39	1,024	838	1,862	8.9	395	355	750	11.2
40–44	942	767	1,709	8.2	344	288	632	9.4
45–49	767	723	1,490	7.2	360	281	641	9.6
50–54	734	681	1,415	6.8	319	212	531	7.9
55–59	562	517	1,079	5.2	212	179	391	5.8
60–64	601	536	1,137	5.4	173	166	339	5.1
65–69	596	591	1,187	5.7	173	168	341	5.1
70–74	516	527	1,043	5.0	134	155	289	4.3
75 or over	925	1,035	1,960	9.4	224	284	508	7.6
Total	10,877	9,961	20,838	100.0	3,522	3,170	6,692	100.0

TABLE 3

Average ages of White first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to mental disorders and place of birth

MENTAL DISORDERS	BORN IN NEW YORK STATE			BORN IN UNITED STATES, EXCLUDING NEW YORK STATE		
	Males	Females	Total	Males	Females	Total
General paresis	45.3 ± 0.3	43.8 ± 0.5	44.9 ± 0.3	46.2 ± 0.4	41.2 ± 0.7	44.7 ± 0.4
Alcoholic	45.2 ± 0.2	44.2 ± 0.6	45.1 ± 0.2	45.2 ± 0.3	42.3 ± 0.7	44.8 ± 0.3
With cerebral arteriosclerosis	68.5 ± 0.1	68.4 ± 0.2	68.4 ± 0.1	68.4 ± 0.3	68.4 ± 0.3	68.4 ± 0.2
Senile	77.1 ± 0.2	77.0 ± 0.2	77.0 ± 0.1	76.6 ± 0.4	76.4 ± 0.3	76.5 ± 0.2
Manic-depressive	38.7 ± 0.4	36.8 ± 0.2	37.4 ± 0.2	48.8 ± 0.6	37.0 ± 0.4	37.6 ± 0.3
Dementia praecox	29.0 ± 0.1	30.8 ± 0.1	29.8 ± 0.1	30.9 ± 0.2	33.3 ± 0.2	32.1 ± 0.2
All first admissions	44.1 ± 0.1	45.7 ± 0.1	44.9 ± 0.1	44.6 ± 0.2	45.8 ± 0.2	45.2 ± 0.1

migrant and non-migrant first admissions were 45.2 and 44.9 years, respectively. The greatest difference occurred with respect to dementia praecox, and in this group migrants and non-migrants had average ages of 32.1 and 29.8 years, respectively, a difference of only 2.3 years. Thus, though the migrant first admissions were older in the functional groups, and slightly younger in the others, the differences do not appear to be of an order which would unduly influence the comparisons of rates of first admissions.

Reference to table 4 will show that the migrant white population had higher rates than the non-migrants in each group of mental disorders. Migrants and non-migrants had average annual rates of 43.4 and 22.4, respectively, with respect to dementia praecox. Psychoses with cerebral arteriosclerosis ranked second, the rates being 21.6 and 11.7 for migrants and non-migrants, respectively. The greatest relative excess was with respect to general paresis, migrants having a rate of 11.1, compared with 3.4 for non-migrants. The former was in excess by over 200%. The alcoholic psychoses also ranked high among migrants.

We may make similar comparisons for native Negroes living in New York State. There were 3,461 such first admissions to all hospitals for mental disease during the three years which ended June 30, 1941. Of this total, 484, or 14.0%, were born in New York State, and 2,977, or 86.0%, were born elsewhere in the United States. Of the entire American-born population of New York State on April 1, 1940, only 15.8% were born in other states. The percentage for the corresponding non-white population of New York State (which was almost entirely Negro) was 63.5. It is therefore apparent that the Negro population was overwhelmingly migrant.

On April 1, 1940 there were 571,221 Negroes living in New York State, of whom 519,935, or 91.0%, were born in the United States. These native-born Negroes had an average annual rate of first admissions of 221.9 per 100,000 population. Corresponding rates for Negroes born in New York State and those born elsewhere in the United States cannot be computed with complete accuracy, since the federal census of April 1, 1940 did not classify Negroes by place of birth. Such data were given, however, for the non-white population. The total for the latter in New York State was 599,596, of whom 571,221, or 95.3% were Negro. The use of the non-white population as a base will therefore give a very close approximation to the rates for Negroes in New York State. On this basis, there was an average annual rate of first admissions of

TABLE 4

Average annual rates of first admissions to all hospitals for mental disease in New York State, 1939-1941, per 100,000 population, for the native white population, classified according to mental disorders and place of birth

MENTAL DISORDERS	BORN IN NEW YORK STATE			BORN IN UNITED STATES, EXCLUDING NEW YORK STATE		
	Males	Females	Total	Males	Females	Total
General paresis	4.9 ± 0.2	2.0 ± 0.1	3.4 ± 0.1	16.2 ± 1.1	6.3 ± 0.6	11.1 ± 0.6
With other syphilis of central nervous system	0.9 ± 0.1	0.4 ± 0.1	0.6 ± 0.1	2.2 ± 0.4	0.9 ± 0.2	1.5 ± 0.2
Alcoholic	8.2 ± 0.3	1.4 ± 0.1	4.8 ± 0.2	25.8 ± 1.4	4.3 ± 0.5	14.6 ± 0.7
With cerebral arteriosclerosis	12.5 ± 0.4	10.9 ± 0.3	11.7 ± 0.2	23.9 ± 1.3	19.4 ± 1.1	21.6 ± 0.9
Senile	6.2 ± 0.3	8.1 ± 0.3	7.2 ± 0.2	8.4 ± 0.8	14.8 ± 1.0	11.7 ± 0.6
Manic-depressive	4.7 ± 0.2	9.6 ± 0.3	7.2 ± 0.2	10.0 ± 0.8	20.3 ± 1.2	15.3 ± 0.7
Dementia praecox	23.7 ± 0.5	21.0 ± 0.4	22.4 ± 0.3	43.8 ± 1.8	43.1 ± 1.7	43.4 ± 1.2
All first admissions	85.2 ± 1.0	76.5 ± 0.9	80.8 ± 0.7	184.8 ± 3.6	155.4 ± 3.2	169.6 ± 2.4

85.6 per 100,000 population for Negroes born in New York State. Negroes born elsewhere in the United States had an average annual rate of 302.7. The latter rate is in excess by more than 250%. However, the great disparity is undoubtedly due in part to the fact that migrant Negroes are older than those born in New York State, differing in this respect from migrants in general. We do not have the age distributions of the native Negro populations according to place of birth. But there are indirect reasons for assuming differentials with respect to age.

Table 5 shows, for example, that 36.6% of the Negro first admissions born in New York State were diagnosed as dementia praecox, compared with 27.5% of the migrant group. On the other hand, the latter were in excess among first admissions with general paresis and alcoholic psychoses, groups with an age range higher than that for dementia praecox. There was a similar difference with respect to psychoses with cerebral arteriosclerosis. These imply that the migrant group was drawn from an older population. Negro first admissions born in New York State had an average age of 36.3 years, compared with 43.1 for the migrant Negroes. Such differences make it clear that the total populations from which the patients were drawn must have differed in the

TABLE 5

Native Negro first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to mental disorders, and place of birth

MENTAL DISORDERS	BORN IN NEW YORK STATE				BORN IN UNITED STATES, EXCLUDING NEW YORK STATE			
	Males	Females	Total Number	Total %	Males	Females	Total Number	Total %
General paresis	32	10	42	8.7	338	138	476	16.0
Alcoholic	27	15	42	8.7	277	90	367	12.3
With cerebral arteriosclerosis	28	25	53	11.0	218	252	470	15.8
Senile	9	17	26	5.4	57	84	141	4.7
Involutional	1	2	3	0.6	6	36	42	1.4
Manic-depressive	6	9	15	3.1	25	66	91	3.1
Dementia praecox	100	77	177	36.6	370	449	819	27.5
Other	69	57	126	26.0	332	239	571	19.2
Total	272	212	484	100.0	1,623	1,354	2,977	100.0

same direction with respect to age. Therefore, the crude rates of first admissions exaggerate the differences between the migrant and non-migrant Negroes. Nevertheless, the rates differ so widely that it may be concluded, for practical purposes, that adjustment for age, were the data available, could not remove the differentials with respect to average annual rates of first admissions.

TABLE 6

Native Negro first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to age and place of birth

AGE (YEARS)	BORN IN NEW YORK STATE				BORN IN UNITED STATES, EXCLUDING NEW YORK STATE			
			Total				Total	
	Males	Females	Number	%	Males	Females	Number	%
Under 15	18	10	28	5.8	19	8	18	0.6
15–19	40	29	69	14.3	64	71	135	4.5
20–24	48	24	72	14.9	121	114	235	7.9
25–29	34	30	64	13.2	177	171	348	11.7
30–34	27	19	46	9.5	225	176	401	13.4
35–39	17	19	36	7.4	204	156	360	12.1
40–44	23	10	33	6.8	173	118	291	9.8
45–49	11	12	23	4.8	168	105	273	9.2
50–54	20	8	28	5.8	129	79	208	7.0
55–59	5	10	15	3.1	91	74	165	5.5
60–64	5	13	18	3.7	80	61	141	4.7
65–69	12	8	20	4.1	71	78	149	5.0
70–74	5	6	11	2.3	55	46	101	3.4
75 or over	7	14	21	4.3	55	97	152	5.1
Total	272	212	484	100.0	1,623	1,354	2,977	100.0

Table 8 summarizes the average annual rates of first admissions for the leading groups of mental disorders in the native Negro population. The highest rate occurring among both migrants and non-migrants was with respect to dementia praecox. The former had a rate of 31.3 per 100,000 population, far in excess of that for any other group of mental disorders. This was due in large part to the relative youth of the non-migrants. On the other hand, the migrants had a rate of 83.3 per 100,000 population for dementia praecox. The difference is clearly significant, since the migrant group is surely older than the non-migrants,

TABLE 7

Average ages of Native Negro first admissions to all hospitals for mental disease in New York State, 1939-1941, classified according to mental disorders, and place of birth

MENTAL DISORDERS	BORN IN NEW YORK STATE			BORN IN UNITED STATES, EXCLUDING NEW YORK STATE		
	Males	Females	Total	Males	Females	Total
General paresis	42.7 ± 1.7	47.0 ± 3.3	43.7 ± 1.5	43.6 ± 0.4	41.9 ± 0.7	43.1 ± 0.3
Alcoholic	38.4 ± 1.2	34.8 ± 1.4	37.1 ± 0.9	41.0 ± 0.6	38.0 ± 0.7	40.3 ± 0.4
With cerebral arteriosclerosis	61.1 ± 1.4	65.5 ± 1.4	63.2 ± 1.0	63.8 ± 0.4	64.6 ± 0.4	64.2 ± 0.3
Senile	73.6 ± 1.8	76.3 ± 1.5	75.4 ± 1.1	74.9 ± 0.8	75.4 ± 0.6	75.2 ± 0.5
Manic-depressive	25.0 ± 1.3	28.1 ± 1.8	26.8 ± 1.2	34.1 ± 1.5	33.6 ± 0.8	33.8 ± 0.7
Dementia praecox	25.7 ± 0.6	29.4 ± 0.8	27.3 ± 0.4	30.4 ± 0.3	32.0 ± 0.3	31.3 ± 0.2
All first admissions	34.3 ± 0.7	38.9 ± 0.9	36.3 ± 0.6	42.8 ± 0.3	43.4 ± 0.3	43.1 ± 0.2

TABLE 8

Average annual rates of first admissions to all hospitals for mental disease in New York State, 1939-1941, per 100,000 population, for the American-born Negro population, classified according to mental disorders and place of birth

MENTAL DISORDERS	BORN IN NEW YORK STATE			BORN IN UNITED STATES, EXCLUDING NEW YORK STATE		
	Males	Females	Total	Males	Females	Total
General paresis	11.6 ± 2.4	3.4 ± 1.3	7.4 ± 1.3	78.1 ± 5.0	25.1 ± 2.4	48.4 ± 2.6
With other syphilis of central nervous system	2.9 ± 1.2	3.4 ± 1.3	3.2 ± 1.1	18.9 ± 3.6	9.8 ± 1.6	13.8 ± 1.4
Alcoholic	9.8 ± 2.2	5.2 ± 1.6	7.4 ± 1.3	64.0 ± 4.4	16.3 ± 2.0	37.3 ± 2.3
With cerebral arteriosclerosis	10.2 ± 2.2	8.6 ± 2.0	9.4 ± 1.5	50.4 ± 4.0	45.8 ± 3.4	47.8 ± 2.6
Senile	3.3 ± 1.3	5.8 ± 1.6	4.6 ± 1.1	13.2 ± 2.0	15.3 ± 1.9	14.3 ± 1.4
Manic-depressive	2.2 ± 1.0	3.1 ± 1.2	2.6 ± 0.8	5.8 ± 1.4	12.0 ± 1.7	9.3 ± 1.1
Dementia praecox	36.3 ± 4.2	26.5 ± 3.5	31.3 ± 2.7	85.4 ± 5.2	81.5 ± 4.4	83.3 ± 3.4
All first admissions	98.9 ± 7.0	72.9 ± 5.8	85.6 ± 4.5	374.9 ± 10.6	245.9 ± 7.8	302.7 ± 6.4

and therefore could not have been affected adversely in such a comparison by differential age distribution alone. It is a reasonable conclusion that the migrants had a higher probability of dementia praecox.

Negro migrants had higher rates of first admissions than the non-migrants in each of the major groups of mental disorders. The differences were marked with respect to the syphilitic disorders and alcoholic psychoses. Migrants had an average annual rate of 48.4 per 100,000 population with general paresis. The rate for psychoses with other syphilis of the central nervous system was 13.8. The combined rate for the syphilitic psychoses was 62.2, compared with 10.6 for the non-migrants. Unquestionably, a large part of the difference was due to age differentials, the non-migrant group including a large percentage from 30 to 50 years of age, the period of maximum risk for such mental disorders. Age also accounts in part for the excess of the alcoholic psychoses among the migrants. The latter had a rate of 37.3, compared with 7.4 among non-migrants. It is very likely, however, that the rates for migrants would remain significantly higher, even were statistical adjustments for age available.

We may conclude with a comparison of average annual rates of first admissions among whites and Negroes during the three fiscal years ended June 30, 1941. (See Table 9)

Negroes born in New York State had an average annual rate of first admissions of 85.6 per 100,000 population, compared with a rate of 80.8 for the corresponding white population. The excess amounts to only six per cent. In view of the fact that Negroes in New York State were younger than the white population, as shown by the United States census ('40), and the certainty that this must have been even truer of the segments of these populations born in New York State, we may conclude that Negroes born in New York State had a higher rate of first admissions than whites. Despite the absence of adequate age statistics, we may also conclude that the great excess of rates among non-migrant Negroes with respect to general paresis, other syphilis of the central nervous system, and the alcoholic psychoses, is also significant. In the case of dementia praecox, the rate for Negroes was in excess by 40%. It is probable that despite differences in age, the rate for the Negro migrants was higher. Rates of first admissions with psychoses with cerebral arteriosclerosis and with senile psychoses were lower among Negroes than among whites. But as the Negro population born in New York was still relatively young, this result may well be spurious. In the

TABLE 9

Average annual rates of first admissions to all hospitals for mental disease in New York State, 1939-1941, among native Whites and native Negroes, per 100,000 corresponding population

	NATIVE WHITES			NATIVE NEGROES			NEGROES VERSUS WHITES	
MENTAL DISORDERS	Born in New York State (a)	Born in United States, excluding New York State (b)	$\frac{b}{a}$	Born in New York State (c)	Born in United States, excluding New York State (d)	$\frac{d}{c}$	$\frac{c}{a}$	$\frac{d}{b}$
General paresis	3.4 ± 0.1	11.1 ± 0.6	3.26	7.4 ± 1.3	48.4 ± 2.6	6.54	2.18	4.36
With other syphilis of central nervous system	0.6 ± 0.1	1.5 ± 0.2	2.50	3.2 ± 1.1	13.8 ± 1.4	4.31	5.33	9.20
Alcoholic	4.8 ± 0.2	14.6 ± 0.7	3.04	7.4 ± 1.3	37.3 ± 2.3	5.04	1.54	2.21
With cerebral arteriosclerosis	11.7 ± 0.2	21.6 ± 0.9	1.84	9.4 ± 1.5	47.8 ± 2.6	5.09	0.80	2.21
Senile	7.2 ± 0.2	11.7 ± 0.6	1.63	4.6 ± 1.1	14.3 ± 1.4	3.11	0.64	1.22
Manic-depressive	7.2 ± 0.2	15.3 ± 0.7	2.13	2.6 ± 0.8	9.3 ± 1.1	3.58	0.36	0.61
Dementia praecox	22.4 ± 0.3	43.4 ± 1.2	1.94	31.3 ± 2.7	83. 3 ± 3.4	2.66	1.40	1.92
All first admissions	80.8 ± 0.7	169.6 ± 2.4	2.10	85.6 ± 4.5	302.7 ± 6.4	3.54	1.06	1.78

case of the manic depressive psychoses, however, it is possible that the lower rate for Negroes may prove to be significant.

In comparing the migrant population, we find an overall excess of 78% for Negroes. The excess among migrant Negroes was especially high with respect to the psychoses of syphilitic origin and was also high for the alcoholic psychoses and psychoses with cerebral arteriosclerosis. It is improbable that these differences could be accounted for by the relative age distributions of the two populations. An excess of 92% on the part of the Negro migrants over the white migrants with respect to dementia praecox must be regarded as significant, since the Negro migrant population belongs to age groups in which this disorder would tend to be relatively low in frequency. Only with respect to the manic-depressive psychoses do white migrants apparently have a higher rate than Negro migrants.

SUMMARY

The native-born population of New York State may be divided into those who were born in New York and those who were born elsewhere in the United States. These groups may be considered as non-migrants and migrants, respectively. From this point of view, separate comparisons were made for the white and Negro populations of New York State, based upon average annual rates of first admissions to all hospitals for mental disease in New York State during the three fiscal years ended June 30, 1941. Among the native whites, the indigenous and migrant groups had rates of 80.8 and 169.6 per 100,000 corresponding populations. The rates for the migrant whites exceeded those of the indigenous population for each of the major groups of mental disorders, the disparity being greatest for psychoses of syphilitic origin, and alcoholic psychoses.

Negroes showed similar differences. Migrant Negroes had an average annual rate of first admissions of 302.7 per 100,000 population, compared with 85.6 for the indigenous Negroes. The rates for Negro migrants were in excess in all major groups of mental disorders, but the differences were especially high for the psychoses of syphilitic origin, the alcoholic psychoses, and psychoses with cerebral arteriosclerosis. The ratios of the rates for Negro migrants to those for non-migrants were much greater than the corresponding ratios for the white population. This is probably due, in part, to the fact that the indigenous Negroes are undoubtedly very young in comparison with the migrants. The age differences are probably not so marked among the white populations.

It is therefore clear that rates of mental disease are higher for migrants than for non-migrants. It is also clear, that, with the exception of the manic-depressive psychoses, Negroes had higher rates than whites. This was true whether we compared the two migrant or the two non-migrant groups. The question therefore arises whether the differences between migrants and non-migrants are due to the action of selective, constitutional factors, or to environmental influences associated with or resulting from migration. A similar question arises with respect to the racial comparisons. Are the rates for Negroes in excess because of racial or social factors? The data of the present study cannot answer these questions definitely. There are suggestions, however, that social factors cannot be ignored. These are discussed elsewhere by Malzberg, Lee and Thomas ('56). The greatest relative excesses of migrants over non-migrants, among both whites and Negroes, were with respect to the psychoses of syphilitic origin and the alcoholic psychoses. The ratios were especially high among Negroes. Since these psychoses have a predominantly social background, especially among Negroes, it may be inferred that deleterious social influences are likely to be operative on a larger scale among migrants than among non-migrants.

We may note that the crude rates of first admissions increased significantly between 1930 and 1940. For the indigenous white population, the rates increased from 44.6 to 80.8 per 100,000 population. For the migrant group, the rates increased from 156.9 to 169.6. In the case of the Negroes, the comparisons were as follows: Non-migrants, 40.0 and 85.6; migrants, 185.5 and 302.7. The increases are probably due, in part, to the fact that the general populations included a higher proportion of elderly persons in the latter years. However, studies by Malzberg ('55) of the total population in which the factor of age was held constant all indicate that there was a real increase in rates of first admissions between 1930 and 1940. It is therefore probable that the crude rates of the present study also indicate a real increase.

Finally, we may note the interesting fact that general paresis has been decreasing steadily for several decades. The non-migrant whites showed a decline from a rate of 3.8 per 100,000 population in 1930 to 3.4 in 1940. For the migrant whites the corresponding rates were 15.3 and 11.1, respectively. Among Negroes, however, the trend was in the opposite direction. The rates increased among non-migrant Negroes from 4.3 in 1930 to 7.4 in 1940. They increased among migrant Negroes from 36.3 to 48.4. General paresis thus increased among Negroes at the very time when the disorder was decreasing in the remainder of the population. General paresis is a disease of syphilitic origin, and it is therefore evident that syphilis was not only more prevalent among Negroes than among the whites, but that the later manifestations in the form of involvement of the central nervous system were also more prevalent. It is generally agreed that the prevalence of syphilis is a social rather than a constitutional or racial problem. Furthermore, for obvious reasons, syphilis is more likely to be present in a migrant population. Therefore, we must bear in mind the possibility that higher rates of mental disease among Negroes may be associated with environmental factors.

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ON BASIC PRINCIPLES IN DENTAL STATISTICS

BY JAAKKO KIHLBERG AND KALEVI KOSKI

Institute of Occupational Health and University of Helsinki, Helsinki, Finland

INTRODUCTION

IN current dental statistical literature, diversity exists both as to statistical presentation and as to methods and concepts (Bransby and Parfitt '52, Ekman '48, Hurme '48 and '49, Jackson '48 and '50, Klein, Palmer and Kramer '37, Klein and Palmer '41, Klein '43, Palmer, Klein and Kramer '38). It is not always possible to perform direct comparisons between two related published investigations: averages and other statistical characteristics used may have been calculated in different ways; basic tabulations also may be essentially different. Further, the concepts adopted in discussion are likely to remain unclarified, consequently causing confusion in conclusions and recommendations.

In our opinion, it is therefore useful to discuss some of the main problems in dental statistics. The contents of this paper will be theoretical, for two main reasons. First, it is of course necessary to build the theoretical framework before actual investigations can be carried out. Second, it does not seem easy to get suitable raw data from the present literature to illustrate our model with practical applications. We feel, however, that while we are looking for and collecting such data, it might interest some students of dentistry to know of the theoretical basis which we propose to use for our later studies. It is our hope that we could, in the near future, come forth with another paper dealing with practical applications of the ideas presented in the following.

To begin with, we will present a simple general model, *i. e.*, a statistical framework within which a logical dental statistical system can be developed. For the sake of clarity the model has to be mathematical in character. The conclusions, however, will form a group of practical recommendations.

A GENERAL MODEL

Consider a population, a group of human individuals of equal age, in ideal observation conditions so that it is possible to perform a complete investigation of dental conditions in the population at any age x (years, say). A series of such observations made at successive ages would then form a longitudinal survey. In such a survey the teeth may be classified exclusively according to the following scheme, this scheme being valid for each tooth locus separately, similarly for deciduous and permanent teeth:

1) The tooth has not yet erupted (state O);

2) The tooth has erupted and is sound (S):

3) The tooth is in the mouth but has been attacked by caries once or more times, being filled or not (K);

4) The tooth is lost (exfoliated, extracted), and was sound when deceding (E);

5) The tooth is lost (exfoliated, extracted), and belonged to the state K (see above) when deceding (D).

In respect to each tooth locus separately, the population can then be classified into the above five classes; *i.e.*, it can be determined what percentage of the individuals have a given tooth erupted, lost, etc. Denote these percentages by

$$O_x,\ S_x,\ K_x,\ E_x \text{ and } D_x,$$

the capital letters referring to the above classification, and the subindex x indicating that the percentages have been determined at the age x. As the classification used is complete, the percentages must add up to 100, *i.e.*,

$$O_x + S_x + K_x + E_x + D_x = 100, \tag{1}$$

whatever be the age x.

If a series of age-specific percentages O_x, S_x, etc. are plotted against the age, together they will form a curve pattern as shown in figure 1. Each tooth locus possesses its own curve pattern, whence a collection of 32 (or 16, if no difference is made between the right and left side) graphs is needed to describe the entire tooth history of the population. In some respects, this curve pattern resembles that used by Hurme ('49). He proposes the name *collective distribution pattern*.

This is the model to be investigated. In the following, properties of the model will be studied in the hope that some of the practical results would be useful.

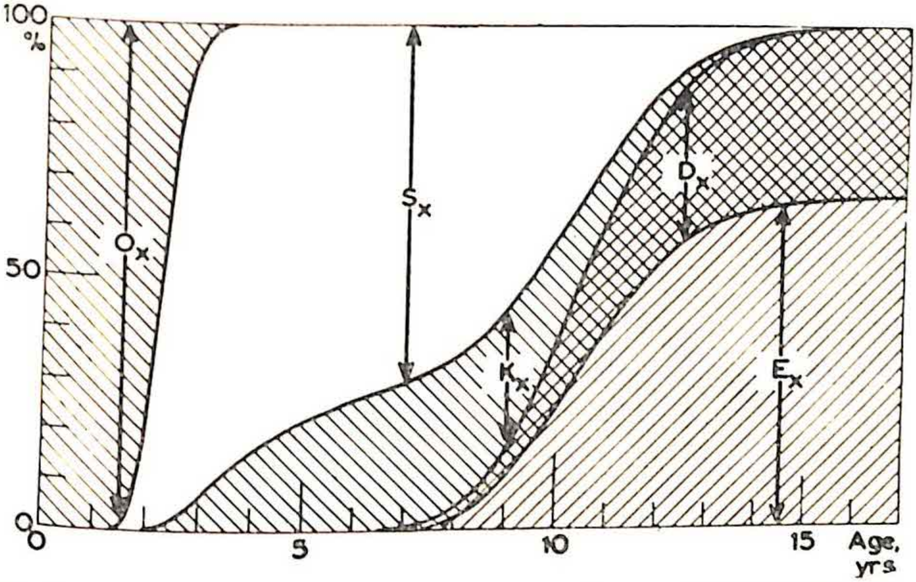

FIG. 1. COLLECTIVE DISTRIBUTION PATTERN FOR A PAIR OF DECIDUOUS TEETH.

ERUPTION

The relative number of non-erupted teeth has been defined as the percentage O_x. The complement of this quantity, *i. e.*,

(2) $$P_x = 100 - O_x,$$

gives the *eruption percentage*. Plotted against the age, the P_x-values will form the well-known eruption curve shown in figure 2.

The rate of growth of this curve during a small age interval dx (mathematically, the first derivative of the curve) is

(3) $$p_x = dP_x/dx,$$

the right-hand side of the above formula representing common mathematical notation for the derivative. This quantity gives the per cent *frequency* or per cent *rate of eruption* during an infinitely small age interval dx in the neighbourhood of the age x. The shape of this eruption rate curve is also shown in figure 2.

The rate above is computed on the total number of loci, *i.e.*, as a proportion of the total population with no regard to the actual states of the tooth loci at the age x. However, some of the loci may have been occupied already so that eruption cannot take place any more. This leads one to calculate another rate in such a way that only the empty tooth loci are considered. This is made by relating the rate of eruption to the proportion of empty tooth loci, thus:

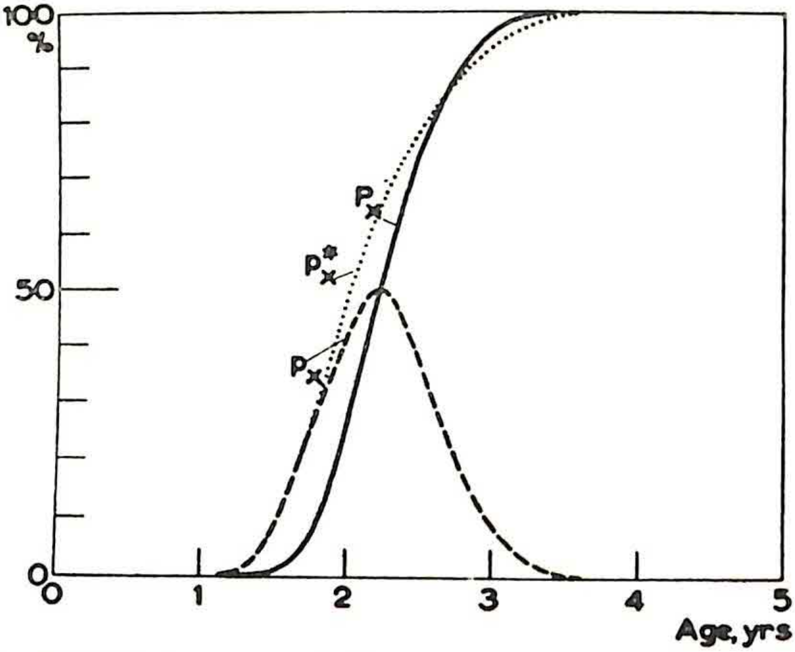

FIG. 2. ERUPTION PERCENTAGE P_x, ERUPTION RATE p_x AND ERUPTION INTENSITY p^*_x AS FUNCTIONS OF THE AGE. THE LAST TWO FUNCTIONS HAVE BEEN CALCULATED PER HALF YEAR.

$$p^*_x = p_x / O_x. \tag{4}$$

The quantity p^*_x gives the probability of an empty locus to become occupied during a small age interval dx. To make a clear distinction from the eruption rate defined in (3) this probability can be called *eruption intensity*. An eruption intensity curve is shown in figure 2. It is to be noted that the shape of the intensity curve in this case is not typical for all teeth, for in some cases, *e.g.*, third molars, lateral incisors, etc. the curve may have a maximum followed by a decreasing tail.

Mathematically, both the eruption rate and the eruption intensity above have been calculated for a very small age interval dx. The numerical values of these quantities can, however, be calculated, *e.g.*, per half year, as is the case in figure 2.

It should be noted that the three curves discussed above are by no means different things, for they are connected with each other by strictly defined mathematical relations. In fact, whenever one of the curves is given the other two can be deduced. The curves only describe the eruption process from different angles.

CARIES

In this model, only primary caries is considered, *i. e.*, the first attacks of caries, whereas no allowance is made for further attacks or for the natural progress of active caries. Further, no attention has been paid to the varying caries susceptibility of different tooth surfaces. Therefore, the model describes the caries phenomenon from a relatively narrow angle of view only. On the other hand, we believe that by accepting *temporarily* these limitations clarity will be won in a point where more detailed theoretical presentation is likely to become heavy and complicated. In further development of the theory now outlined, more attention can be paid to all the complications inherent in caries statistics.

At any age x, the total relative number of individuals having had some caries experience in a given tooth is evidently

(5)
$$C_x = K_x + D_x,$$

for the percentages K_x and D_x include all cases attacked by caries, with no regard to whether the attacked tooth is left in the mouth or not. The C_x-curve is a non-decreasing curve of the type shown in figure 3.

The first derivative of this curve

(6)
$$c_x = dC_x/dx$$

gives the per cent rate of primary caries attacks during a small age interval dx in the neighbourhood of the age x. This quantity can be called *caries attack rate*. In figure 3 a c_x-curve deduced from the C_x curve is shown, the numerical rate having been computed per half year as above.

However, all the loci are not necessarily occupied by sound teeth which can be exposed to the risk of primary caries. Therefore, it is advisable to calculate another rate, taking into consideration only the teeth actually exposed to this risk. So the quantity

(7)
$$c^*_x = c_x/S_x$$

is obtained. Evidently, this quantity gives the proportion of sound teeth developing primary caries in the small age interval dx, so that it can be called primary *caries attack risk* or *attack intensity*. On the basis of the C_x curve in figure 3 a c^*_x curve has been computed according to formula (7). This curve is also shown in figure 3.

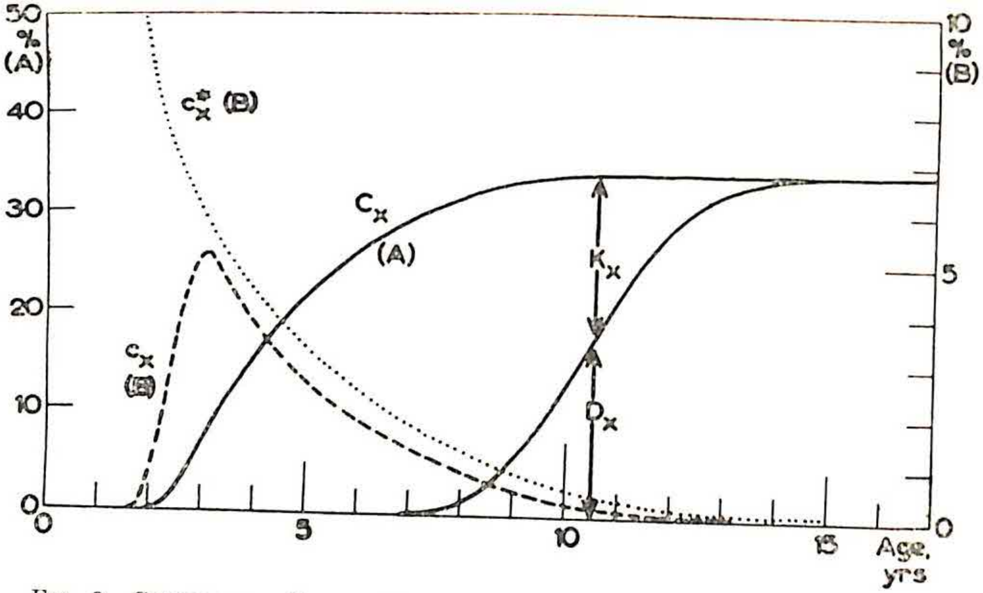

FIG. 3. CUMULATED CARIES PERCENTAGE C_x, CARIES ATTACK RATE c_x AND CARIES ATTACK INTENSITY c^*_x AS FUNCTIONS OF THE AGE. THE LAST TWO FUNCTIONS HAVE BEEN CALCULATED PER HALF YEAR.

The three curves defined by (5), (6) and (7) are closely related to each other, as is evident from the presentation. Each of them, describing the caries process from a particular point of view, possesses interesting properties which probably have been only partly recognized. For example, the c^*_x function presents a useful tool in making comparisons between different populations exposed to the risk of primary caries, or between different teeth within the same population (Ekman, '48).

For some practical purposes, the model above certainly is too simple, as no allowance has been made for the natural progress of caries or for repeated carious involvement, and as the different tooth surfaces have not been treated separately. However, improvements and refinements in the theory can easily be made in line with the presentation. For example, if the observation conditions allow, the primary attack risk curve can be replaced by a general attack risk curve, with no reference to the number of previous attacks.

EXFOLIATION AND EXTRACTIONS

The total loss percentage at an age x, Q_x, is composed of the two percentages E_x and D_x defined above, being the sum of them. Plotted against the age, the curves E_x and D_x and, consequently, $Q_x = E_x + D_x$ are of the non-decreasing type shown in figure 4.

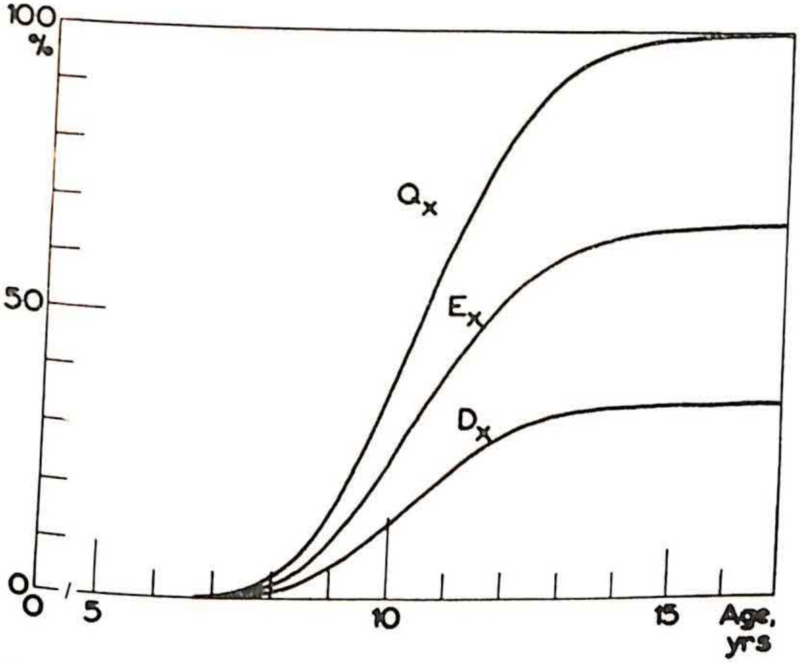

FIG. 4. LOSS PERCENTAGES E_x AND D_x, AND THE SUM OF THEM, Q_x.

Taking the derivatives of these curves, three *loss rates* are obtained, *viz.*

(8)
$$e_x = dE_x/dx$$
for sound teeth,

(9)
$$d_x = dD_x/dx$$
for carious teeth, and

(10)
$$q_x = e_x + d_x \; (= dQ_x/dx)$$
for all teeth, the last rate, of course, being the sum of the previous two. Actual rate curves calculated on the basis of the above loss percentage curves are shown in figure 5.

The rates above have been calculated for the total number of tooth loci in the population. However, one is often more interested in the *risk* than in the rate of loss. All the tooth loci are not exposed to this risk, but only the teeth left in the mouth. For the sound teeth, the relative number of teeth exposed to the loss risk is S_x, for the attacked teeth correspondingly K_x, the sum of them, $S_x + K_x$, finally representing the total proportion of teeth exposed to the loss risk. So the risk functions can be calculated as follows:

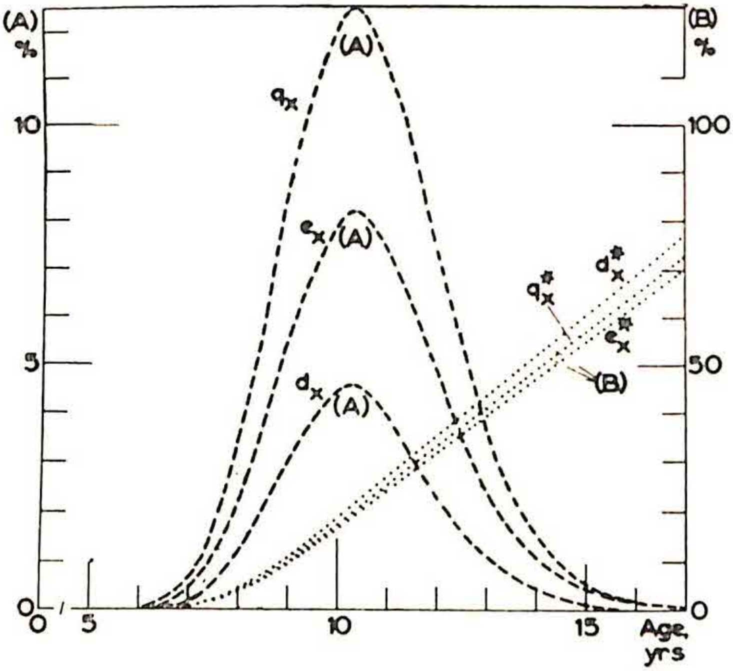

FIG. 5. LOSS RATES e_x (FOR SOUND TEETH), d_x (FOR CARIOUS TEETH) AND q_x (TOTAL), AND LOSS RISKS e^*_x, d^*_x AND q^*_x. THE FUNCTIONS HAVE BEEN CALCULATED PER HALF YEAR. N. B.: SCALE *A* FOR RATE CURVES, SCALE *B* FOR RISK CURVES.

$$e^*_x = e_x / S_x \tag{11}$$

for sound teeth,

$$d^*_x = d_x / K_x \tag{12}$$

for attacked teeth, and finally

$$q^*_x = q_x / (S_x + K_x) \quad (= q_x / T_x, \text{ where } T_x = S_x + K_x) \tag{13}$$

as the over-all loss risk. These risk curves are also shown in figure 5.

The life-table technique presented above is in line with that applied by Klein ('43), although he does not treat different teeth separately.

At first sight one may think that the sub-division of the group of lost teeth applied above is superfluous, *i.e.*, that a sufficient and satisfactory theoretical model could be built by means of the quantities Q_x, q_x and q^*_x alone, especially as in practice it is very difficult if not impossible to discriminate between the classes E and D. However, the sub-division applied is there for the sake of adequate treatment of caries process in the model. The presentation concerning caries statistics above contains the quantity C_x where D_x but not E_x is included, see formula (5), whence the sub-division is a necessity.

DISCUSSION

The model presented above forms a basis for a logical system of dental statistics, details of which will be presented in another paper. Of course, the framework suggested for this purpose is not unique, but represents a plausible alternative among those possible. It may be considered a weakness of this system that various tooth surfaces, different intensity degrees of single caries attacks and the like are not given attention here, in spite of the fact that many of the dental studies in the past have especially emphasized the importance of these factors in thorough dental statistical investigations. Taking into consideration this kind of additional factors would, however, in our opinion, make the model unduly complicated at this stage. Indeed, we believe that most of the requirements of efficient and logical dental statistics will be met already within this framework. As pointed out in several passages, refinements are possible in details where more accurate description of actual relations is desirable.

As to statistical characteristics, one important property of the model can be noted already in this paper. This is the *time division* actually performed by the curves which were defined by the formula (1). If the height of figure 1, denoted by 100%, is understood to be equal to unity, then the area limited by the horizontal zero and 100% lines, and the vertical zero line, can be expressed in time dimension. Consequently, the curves shown in figure 1, starting from the horizontal zero line and reaching up to the 100% line, divide this "time area" in time periods. For example, the area to left from the P_x curve, *i.e.*, the O-area is simply equal to the mean eruption age, the S-area equal to the mean sound mouth-age, this together with the K-area equal to the total mouth-age, and, finally, the sum of O-, S- and K-areas equal to the mean deceding age. Remembering that the K- and D-areas together represent the attacked teeth it can be seen that their relative magnitude gives an indication of the power of caries in the population. Indeed, statistical characteristics of caries can be developed from these area considerations.

SUMMARY

We suggest a system of dental statistics based on simple classification of teeth in five exclusive classes:

1) Tooth not erupted;
2) Tooth in the mouth, sound;
3) Tooth in the mouth, attacked by caries;
4) Tooth lost while sound;
5) Tooth lost while attacked by caries.

It is proposed that a series of age-specific per cent distributions of the tooth loci into these classes, or a collective distribution pattern, be used for each tooth separately as a basis of further statistics. Main properties of the model are discussed, and a number of auxiliary functions derived and presented. Mathematically, these derivations are closely related to so-called life-table technique.

ACKNOWLEDGMENT

We wish to express our gratitude to Dr. Veikko O. Hurme who has read the manuscript. His suggestions have been of great value in the final preparation of the work.

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BOOK REVIEWS

Evolution, Genetics, and Man. By THEODOSIUS DOBZHANSKY. 398 pp. Wiley, New York, 1955. $5.50.

In these boom-days of science two divisions of labor have appeared, (a) between specialists in research in different disciplines and subdisciplines, and (b) between researchers and writers. Most scientists pursue single channels of inquiry and present their results in terse, jargon-laden monographs. Few science writers who open broad fields to the general public have the time or training for special research. Once in a blue moon an original researcher combines a devotion to special pursuits, a general coverage, and the ability to write simply and well. Such a man is Theodosius Dobzhansky.

Evolution, Genetics, and Man is a textbook addressed to the beginner in genetics as well as to students of anthropology, paleontology, and other disciplines in which genetics is peripheral schedule-wise although vital and basic. With a combination of boldness and good judgment the author covers the usual subject matter of standard genetics, including the structure of the chromosome, the mechanics of heredity, mutations and mutation rates, gene frequencies, natural selection, genetic drift, the structure of Mendelian populations, and balanced polymorphism. He explains races as genetically open and species as genetically closed systems with the fact of mating rather than its genetic potentiality as the threshold criterion. Some new species are formed, he says, by polyploid crossings as a quick method of evolution.

Homology, analogy, and the blood precipitation tests are covered. Sex, says Dobzhansky, gives a population its maximum opportunity for variation, and the routine which the male follows in seeking out his mates makes for both differentiation and increased intelligence. In mammals hormones, themselves genetically controlled, play a large role in sexual development. Darwin's idea of sexual selection is replaced by a new theory, that the excess growth of secondary sex characters provides mechanisms for identification and isolation, thus helping species formation.

In a chapter on organic evolution a summary is given of the history of living animal forms and of current theories of evolutionary change. When fish got lungs land forms appeared. When these began to lay shell-covered eggs with built-in rations, land-breeding began, and later mammals and birds took over from reptiles during a period of global crisis, probably thermal in nature. Mammals and birds had the advantages of internal heat-control, and a care of the young.

Evolutionary parallelism, he says, produced the marsupial wolf and the false horse of South America, while the most successful forms arose in the centers of land masses, where competition was keenest. The faunal areas of the world are named and described, and finally, man is born. Dobzhansky firmly rejects the tendency of human paleontologists to give every scrap of bone they find a new generic name. He confines fossil and living men to one genus and two species, *Homo erectus* and *Homo sapiens*. He fails to endorse the popular dogma that man has no instincts and places the acquisition of culture where it belongs, in a biological context.

Rejecting orthogenesis he endorses Simpson's idea of orthoselection—i. e., evolution continues in one direction as long as conditions favorable to it endure. He torpedoes the old tale of the Irish elk—that its antlers grew so big that he became extinct from carrying them around—and answers Berg's objection to mutation and selection as being responsible for the growth of complex organs like the human eye. This eye, he points out, evolved over a long, long time from the invertebrate ancestors of the fishes through many intermediate forms, and was perfected bit by bit over many millions of years.

He defines progress as an increase in the complexity of organs and an improvement in sensory perception and nervous coordination. In his view standard, known principles are good enough to explain the origin and evolution of life. He puts up a convincing argument.

To anyone who has ever tried to write a general book on a wide and highly technical field it is obvious that much work went into this product. In each chapter the subject is gently introduced by a historical narrative and it is ushered out at the end by a lucid summary. In between, in the body of the chapter, Dobzhansky fights the familiar and nearly impossible battle between terminology and clarity. Usually he wins, particularly in the latter two-thirds of the book, but a few slightly sluggish passages still remain in the area of explaining mitosis, meiosis, crossing-over, and related phenomena. He achieves caution throughout without the use of weasel-words, and he achieves humor without jocularity, even joking about the difficulty of pronouncing his own name. In my own special field of racial studies I can find no technical errors important enough to mention in a review. As my field may be the farthest from his of any covered, we can give the book a seal of accuracy.

Evolution, Genetics, and Man is as monumental as its writer, who, combining special experimental knowledge with wide scientific coverage, can also handle a language originally foreign to him with delicacy and skill, to the enlightenment and pleasure of us all. Once again Dobzhansky has done the kind of job we have come to expect of him, and a little more.

CARLETON S. COON

University of Pennsylvania,
Philadelphia, Pennsylvania.

Counseling in Medical Genetics. By SHELDON C. REED. viii + 268 pp. W. B. Saunders Co., Philadelphia, 1955. $4.00.

The principles of human genetics find their practical application when counseling on hereditary problems is sought. This means in most instances that parents who have had a child with a congenital defect or hereditary disease want to know the likelihood of a recurrence of the condition in their offspring.

At present many Institutes provide counseling in hereditary problems: 13 are listed by Dr. Reed for the United States and Canada and I may add that at least 6 are active in Europe. We can foresee a time when ignorance of this branch of medicine will be merely a matter of personal nonchalance of the practitioner. This book is intended as an introduction to the practical aspects of human genetics for physicians. The author is Director of the Dight Institute for Human Genetics in Minneapolis, which started to give genetic advice to patients and physicians in 1941. The accumulated material has provided the basic framework for this book.

It is divided into 29 chapters and an appendix gives a list of inherited diseases with their frequency, if known, and their type of inheritance. Each of the 23 chapters which are devoted to a single subject includes one or more actual counseling cases taken from the files of the Dight Institute. Dr. Reed covers a wide field: common conditions such as twinning, mental retardation, diabetes and allergies are included as well as some rare hereditary diseases such as fibrocystic disease of the pancreas, pyloric stenosis etc. Information is provided on the most common congenital malformations, *i.e.* clubfoot, harelip and cleft palate, dislocation of the hip, congenital heart, anencephaly, spina bifida and mongolism. The two chapters on the genetics of blood groups and of disputed paternity should be of interest for the physician and the public. In the first four chapters emphasis is given to the general, moral and philosophical aspects of genetic counseling. A short chapter is devoted to the genetic effects of ionizing radiation. The reader may be interested to know that problems of skin colour is the major reason for seeking advice at the Dight Institute, followed by epilepsy, consanguinity, mental deficiency, mongolism, schizophrenia, harelip and cleft palate, eye colour, and twinning.

As the topics discussed are many, it is no wonder that some problems appear too simplified and the treatment of others is not based on the most important published reports. On the other hand a book intended as an aid to the practitioner must not exceed a reasonable size. Judging this work as a whole, it is likely that many human geneticists, who are aware of the intricacies of the subject, will not agree with Dr. Reed's tendency to oversimplify counseling problems. The reviewer disapproves of the style of the book. Colloquial and slang words are used to such an extent as to make the reading rather irritating. This puts the actual content, which is mostly good, in a wrong light. I quite agree with plain writing in scientific books but I still believe that a dignified science should be dealt with in dignified language. I am sure that a radical change of the style would improve the value of the book considerably.

M. FRACCARO

State Institute for Human Genetics,
Uppsala, Sweden

Culture and Mental Disorders. By JOSEPH W. EATON and ROBERT J. WEILL. 254 pp. Free Press, Glencoe Illinois, 1955. $4.00.

The earlier analysis of population increase among the Hutterites reported on these pages [1] was part of a larger research. Initially, the aim of the survey was to discover the reasons for an apparent lack of psychiatric disorders in the small, close-knit and socially isolated sect of 8,542 Hutterites in the Great Plains area. The research staff soon found, however, that previous reports were in error; by the use of a thorough screening process which located virtually every mental case (active or recovered) in the entire population, they located 199 persons diagnosed as having had a mental disorder or epileptic seizure [2] at some time. Of these, fifty-three were psychotic.

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[1] Joseph W. Eaton and Albert J. Mayer, "Social Biology of Very High Fertility," Human Biology 25: 206-264, 1953; republished under the title *Man's Capacity to Reproduce*, Glencoe, Illinois, Free Press, 1954.

Although these results were unexpected, the authors made comparative studies with ten other intensively surveyed populations and found the Hutterite lifetime risk of mental disorder to be lower than other groups in the Euroamerican population. Thus the incidence was higher than expected but in the direction hypothesized in the beginning. " More than 97 out of every 100 Hutterites living in 1950 had not experienced a major mental disorder." At the same time they discovered that the Hutterite psychosis rate appeared to be somewhat higher than a comparable one on the island of Formosa (pre-Chiang).

Equally significant was the finding that there was a virtual absence of psychopathic personality, obsessive-compulsive neuroses and psychoses associated with syphilis, alcoholism and drug addiction. This leads the authors to say that " the almost complete prevention of these disorders may be possible within an appropriate social and cultural setting."

The most surprising result of all, however, was the relative incidence of the two " functional " psychoses, schizophrenia and the manic–depressive disorders. Of the fifty-three psychotics 73.6% were manic-depressive (nearly all of the depressed type) ; this is in startling contrast to the mental hospitals in the U. S. where schizophrenics dominate while manic-depressives constitute less than 15% of the first admissions. Eaton and Weill relate this difference to the social cohesion of the Hutterite family and society generally, the stress on rigorous religious duty, and the internalizing of aggressive drives.

Throughout the entire work, representing a fine example of an interdisciplinary study, the writers display scientific caution and qualify their conclusions with commendable judgment. In a final appendix they outline a careful and complete account of the methodology which gives the reader confidence in the validity of the findings. In spite of the important stress on cultural factors in mental disorders,

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[2] 20 of these were epileptics without psychotic or mental defective traits and were included only for sake of completeness.

Eaton and Weill, as a result of their experience with the Hutterites, conclude that there is probably an irreducible minimum of psychosis and neurosis in any society. "Our findings contain no blueprint for a perfect social order. On the contrary, a mental health utopia is probably impossible."

R. A. SCHERMERHORN

Western Reserve University,
Cleveland, Ohio.

Readings in Anthropology. By E. A. HOEBEL, J. D. JENNINGS, and E. R. SMITH. ix and 417 pp. McGraw-Hill, N. Y., 1955. $5.00.

Reviewing a source-book is a tough assignment. At best it is a difficult job, and at worst it is a thankless task. In the first place there are few anthropologists able to encompass scope. In the second place it is not really content that is scanned, but selection. This involves too much second-guessing; as the saying goes, "hindsight always has 20-20 vision." So, I'll put on my trifocals and get to work: one view for knowledge (reasonably acceptable); one for experience (fairly extensive); one for imagination (unlimited).

There are eight Parts in this book: Anthropology, the Study of Man; Prehistory; Physical Anthropology and Race; Primitive Technology; Primitive Society; Language; Society and Culture; Applied Anthropology. I shall here consider only Prehistory, Physical Anthropology and Race, and Applied Anthropology (really Applied Cultural or Social Anthropology).

The authors have aimed at reprinting certain source articles to be read by beginning students. On the whole, the references chosen are acceptable, though, in my opinion, not always the most representative or comprehensive. Under Prehistory are two that must stand challenge. Braidwood's "Prehistoric Men" is far more about stone tools than about hominids. Broom's "The Apemen" reads more like the literary rendition of field notes. I'd have swapped both for Clark Howell's "The place of Neanderthal man in human evolution," or any one of the pithy and concise articles by Le Gros Clark, Straus, or Vallois. "New Light on Ancient Americans" by Linton also raises a point. The article was written in 1951 and in it Linton says, "Since the leader of the *Kon-Tiki* expedition has given professional anthropologists less than their due in his delightful book, ..." This gives the reader a no-longer valid impression. The authors might well have footnoted a reference to Heyerdahl's detailed "American Indians of the Pacific." Frank Roberts' "The Early Americans" and Heizer's "Radiocarbon Dating" are well-chosen.

Under "Physical Anthropology and Race" (why the dichotomy?) there are several references which might well have been alternatives. Because it gives the beginning student a broader perspective I'd have preferred McCown's "The training and education of a physical anthropologist" to the quoted "The New Physical Anthropology" by Washburn. In this essay Washburn says, "The new physical anthropology is primarily an area of interest, the desire to understand the process of primate evolution and human variation by the most efficient techniques available." This, standing by itself, fails to inform the beginner of the dynamics of a physical anthropology that encompasses not only the genetics of apes and fossil man, but the bio-medico-dental problems of modern *living* human beings. I'd like to have also seen readings such as Brožek's "Measuring nutriture," Driver's "Statistics in Anthropology," and Thieme's, "The population as a unit of study." The "new anthropology" must be defined not only in terms of past processes but—even more cogently, I think—in terms of the genetics and the bio-physiology of norms of human development, *today*. The selection of "Adaptive Changes in the Human Body" by Coon, Garn, and Birdsell is the most up-to-date reference in this Part, bringing dynamic thinking to the race problem.

The Part on "Applied Anthropology" leaves Physical Anthropology out in the cold. References by Firth, Tax, and Chapple discuss the application of socio-cultural theories and data to administrative problems. One looks in vain for the applied researches of Hooton, Randall, Russell Newman, Damon, Hertzberg, Evans, and others. The entire realm of Constitutional Medicine is slighted.

The whole business of take-this, leave-this-out might well have been handled by either an explanatory linking paragraph between Parts, or the presentation of alternative or ancillary references. The serious student might then browse further, doing some evaluation on his own.

I guess the whole problem of evaluating what-to-choose can be summed up in the final rather dour sentence of Washburn's "new" article: "There is nothing we do today which will not be done better tomorrow." I guess, maybe, that goes for each article, for the whole volume—*and* for this review!

W. M. KROGMAN

Graduate School of Medicine,
University of Pennsylvania.

The Physical Anthropology of Ireland. By E. A. HOOTON and C. W. DUPERTUIS. xix + 304 pp. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, vol. XXX, Nos. 1-2. $10.00.

Thanks to these 2 volumes, Ireland is now one of the best-described regions in the world. The senior author, Professor E. A. Hooton, completed his part of the work just before his death, and this survey is the climax of his brilliant career. Dr. Dupertuis, who is one of his ablest students, performed the measurements of all the male Irish, and a smaller female sample was measured by Dr. Helen Dawson. This fortunate combination of personnel resulted in a superb example of the Hooton method.

In his lifetime, Professor Hooton and his students produced most of the scholarly literature in the United States on racial and criminal anthropometry. His own major works are meticulous in detail, complex in design, and often witty and controversial. Hooton's interests were strongly eugenic, and his published studies of race, physique and occupation often elicited cacophonous protests from his many critics. At times his surveys became unwieldy and marred by faulty sampling, and his largest enterprise, the survey of American criminals, was characterized by considerable differences in anthropometric technique between the 2 field workers who performed the measurements.

Such flaws are minimal in the Irish survey. Most of the data, dealing with adult Irishmen, were the work of Dupertuis alone. Dr. Dawson's survey of 1,800 women was localized in western Ireland, and is not very fully integrated into the major portions of the text, which grew out of the study of the men.

Considering the time when the male measurements were made (1934-36), Dupertuis' sampling design is surprisingly good, although too few urban Irishmen are included. By travelling over 45,000 miles, Dupertuis measured over 10,000 subjects, and his description of his travels has almost the literary charm of the relaxed and anecdotal Hooton.

Hooton's contributions include an introduction on the civilization of Ireland, the geomorphology and topography of the island, and straightforward description of regional variations in important measurements and morphological observations of the male series. This descriptive account is enhanced by excellent maps. Regional differences in body weight are the only important ambiguity, and the confusion in this picture was forced on Dr. Dupertuis by the necessity of measuring weight with clothing on at all seasons of the year. This limitation of the data is all the more regrettable in view of recent findings on climate and body weight in man by a number of anthropologists.

In considering the maps of morphological features in Ireland, one may object that modern zoogeographic devices such as clines were not used. The regional differences are presented very clearly, however, and some future scholar with keen intuitions may be able to make use of them in studies of the evolutionary dynamics of the Irish population.

Next comes a sorting of the male series into subracial classes or morphological types. This reviewer has criticized the use of this method in reconstructing remote racial history (Am. J. Phys. Anthrop., *13*, pp. 388-389). It is suitable for studies on recent race mixture, assortative mating or occupational preferences, but genetic considerations indicate that it should not be used to sort out supposedly ancestral strains in long-established human populations.

Some interesting relationships among morphological types, age and occupation were found. Nordics, for example, are very scarce. Among the Irish, as in American convicts, Nordics are to a large extent an immature age group rather than a subrace. In Ireland, the Nordics occupy quite undistinguished stations in life, and remind one of the "gentle and furtive" Nordics in American prisons, as described in Hooton's book *Crime and the Man*. Hooton's lifework gives small comfort to anyone who still defends the racial superiority of Nordics.

In the field of racial history, the attempts to relate the regional variations of the Irish to prehistoric migrations are unsuccessful, and this reviewer wonders how convincing this kind of remote analysis can ever be. Ancient Irish crania are rare and localized, and the literature on the racial anthropometry of Great Britain is only fragmentary. Regional traces of the Norse and English invasions seem to be more obvious than those of any earlier peoples. No evidence was found of local enclaves of swarthy or dark-eyed Irishmen, either as descendants of prehistoric immigrants or of such putative recent arrivals as the shipwrecked sailors from the Spanish Armada. This ubiquitous tidbit of Irish folklore can now be dismissed as pure fantasy.

To the racial historian, an important section is the controversy with Professor C. S. Coon on the survival of European "Upper Paleolithic" physical types in Ireland. Coon's great work *The Races of Europe* has as a major thesis the "reduction" or fetalization of the skull in the pre-Neolithic peoples of Europe to produce most of the living populations of the area. Coon thinks that western Ireland shows a minimal amount of this trend. Hooton and Dupertuis contest this verdict, but to this reviewer, Coon's reconstruction still stands.

With all its great merits and lesser faults, the Irish survey is the consummation of Hooton's life work. It is rich in detailed information of value to the historian, archaeologist or biologist. For those who have not the privilege of studying the Irish physiognomy *in situ* or in the Boston subway, the many excellent photographs are a tolerable substitute, and may stimulate many casual readers to enjoy the text as well.

EDWARD E. HUNT, JR.

Forsyth Dental Infirmary,
Boston.

Anthropological and Ophthalmological Studies on the Angmagssalik Eskimos. By ERIK SKELLER. 231 pp. Reprinted from "Meddelelser om Groenland" Bind 107, Nr. 4, Copenhagen, 1954.

Danish anthropology has scored again. The Angmagssalik Eskimos are now one of the best known peoples in respect to both tooth morphology (P. O. Pedersen, 1949, in the same monograph series) and the appearance of the eye and its refraction (the work under review). Furthermore, Skeller has included general anthropometric, anthroposcopic and genetic surveys of this group of East Greenland Eskimo and has related these studies to each other, to other Eskimo studies, to what is known of Mongoloid peoples in general, and to the leading theoretical issues concerning the race concept, race formation and race mixture.

He devotes the first chapter to a brief discussion of the good and evil befalling the Eskimos because of civilization. The second concerns the concept of race in anthropology; contrasting classical anthropometry with the population-genetical method, Skeller concludes that the latter supplements but does not replace the former. The third chapter introduces the geographic distribution of the Eskimos, theories of their migrations, and new archaeological evidence concerning their culture sequences. The rest of the chapter is devoted to the peopling of Greenland and especially Angmagssalik; prehistoric and historic population movements; the question of European admixture on this isolated part of the East Coast; the practice of wife exchange and its relation to genetic studies; and age and sex distribution of the population.

In Chapter 4 Skeller reviews the anthropometric studies of Eskimo skeletons, and of living Eskimos, Indians, and Mongoloids. Chapter 5 takes up each of 39 measurements and observations in turn, reports the author's data, and compares them to some of the findings of previous studies. Chapters 6 and 7 are methodological. Skeller analyzes and rejects use of the typological approach. He discusses the relation of diet to stature, criticizes the coefficient of racial likeness, compares his data with an independent series of the same groups of people measured 15 years earlier by Gessain (in stature, head measurements and bizygometric diameter the agreement is excellent; in sitting height and morphological face height their differences are apparent), and indicates the need for observations of differences between several groups or in many traits because of the possibility of recent random genetic drift in Eskimos.

Chapters 8 and 9 take up the genetic traits: blood groups, iris color, finger prints, etc. The inhabitants of the west coast of Greenland are characterized as a hybrid population intermediate between the Angmagssalik and Danes and Icelanders. This is disclosed more readily by means of the genetically conditioned characteristics than by anthropometric ones.

Chapter 10 concerns the exterior eye. It is an especially thorough discussion of eye folds. In this series the most common adult form has a tarsal fold that leaves the margin free and a marginal fold that originates below the tarsal fold, partly covers the caruncula and ends in the skin of the nose.

Chapter 11 discusses in detail the refraction of the eye. By plotting Eskimo and other refraction curves on probability paper, Skeller shows that they can be explained as the result of two Gaussian curves. He suggests that these represent two genetically different groups and that the Gaussian form represents the effects of exogenous, environmental, factors. Thus the two theories of etiology of myopia, that it is gene-determined and that it is the result of excessive reading or other near work, are ingeniously combined in this hypothesis.

To summarize, this work contains all the usual appurtenances of a monograph in physical anthropology: numerous tables of measurements, front and side view photographs of 21 subjects, liberal citations from the literature, etc. But all this material is focused on a series of problems: the extent of interbreeding, the effects of European diet, the relationship to other Mongoloids, the dominance of green eye color, and a stable and a labile gene determining ocular refraction. The author concludes with 7 suggestions for future study, but the list is too short; the reader may think of more nearly 70.

GABRIEL LASKER

Wayne State University,
Detroit, Michigan.

Growth at Adolescence. By J. M. TANNER. 212 pp. Charles C. Thomas, Springfield, Illinois. 1955. $5.85.

A common complaint among medical educators is that instruction and experience is directed toward the pathologic and the abnormal before an adequate appreciation of the nonpathologic or normal is developed. In no period of life has this been so true as in that dimly defined as adolescence. Temporarily suspended in the limbo between pediatrics and adult medicine, the adolescent passes through a period of anatomic, physiologic and psychologic alterations which approximates rates of change present otherwise only during the first years of life. Many of the alterations have been documented within recent years, partly as a result of "Growth and Development" studies, but no single review of data from diverse sources expressing diverse interpretations has been available until the publication of this monograph. The book covers largely pertinent material from publications which have appeared since 1940, including some of the author's reports from the Harpenden Growth Study. Very little unpublished data is cited. Charts and tables are present, but it should be stressed that this monograph is more of a commentary on data than a compendium like the Watson-Lowrey book. A very helpful feature is the redrawing of previously published graphs to provide greater uniformity and easier comparison throughout the volume.

The author is clearly aware of limitations resulting from studies of small groups, from vagaries of technics, and from damping effects of cross sectional as opposed to longitudinal surveys; he is careful to indicate which conclusions are well founded and which are still open to question. For example, he is careful to point out that ordinary biometric data are well documented and permit operative conclusions, whereas data on sexual dimorphism are sparse and statements based on them are less reliable at the present time. Nevertheless the author is willing to express personal opinions even on subjects in which active researchers may easily find reason for disagreement. This personal touch throughout the book, carrying pleasant intimations of the lecture hall, makes for an extremely readable presentation.

In the sections devoted to physical growth, the author calls attention to the value of graphic representation of annual increments in comparison with the more common cumulative graphs. Variations in velocity of change of any characteristic studied are more easily recognized by this technic. As a corollary, individuals are more effectively compared by holding physiologic status constant than by holding chronological status constant; e. g., menarche, age at peak of growth spurt, etc. The sequence of development of secondary sex characteristics and the variations are described in detail so that anxieties among children and their parents concerning deviations from the expected pattern can be allayed. The multiplicity of criteria for gauging developmental status, and anticipating subsequent growth, should have considerable practical interest for orthopedic surgeons concerned with epiphyseolyses, spine fusions, etc.; they are discussed in a chapter on " Developmental Age and Concept of Physiological Maturity." Extremely valuable chapters are those on " Physiologic Changes at Adolescence " and " The Endocrinology of Adolescence " even if the discussions are largely theoretical. Naturally a section on Mentality and Behavior is included, and the book concludes with comparative data from animal studies and a short section on technics of examination. There are the technics used at the Harpenden Growth Study; they include standard anthropometric examinations, photographs permitting measurements from enlargements, and radiographic examinations of chest, bones, teeth and soft tissues of the extremities. The accuracy of the last mentioned is enhanced by the simple expedient of maintaining the central plane of the limb at a fixed distance from the film (10 cm.). This places a limb of small girth somewhat remote from the film, but from the published illustrations no great loss of detail is recognized. Such loss as is present could be minimized by utilizing one of the recently available 0.3 mm. focal spot x-ray tubes. An extensive bibliography is appended.

Dr. Tanner has rendered a great service in consolidating the information on growth at adolescence and offering interpretations for those less able than he to evaluate the data. He has succeeded in focusing on a relatively neglected, complicated phase of human growth while maintaining its continuity with other phases both earlier and later. His efforts will be appreciated by those to whom he addresses the work in the preface: medical students and their teachers, biologists, anthropologists, and particularly to physicians concerned with children and adolescents.

Frederic N. Silverman

The Children's Hospital,
Cincinnati, Ohio.

BOOK NOTICES

THE EXPRESSION OF THE EMOTIONS IN MAN AND ANIMALS. By Charles Darwin. xi + 372 pp. Philosophical Library, New York, 1955. $6.00. In her brief preface to this edition of a classical treatise, Margaret Mead notes the value of Darwin's inquiry for the present-day study of the non-verbal aspects of human communication ("kinesics"). Eight pages of recent drawings and photographs of expressive behavior were added.

NORADRENALINE. By U. S. von Euler. xxi + 382 pp. Charles C. Thomas, Springfield, Ill., 1956. $11.50. A comprehensive monograph by one of the outstanding investigators on the adrenergic nerve transmitter and suprarenal medullary hormone. Most of the 750 references were published within the last 10 years.

EXCEPTIONAL CHILDREN. By Florence L. Goodenough. x + 248 pp. Appleton-Century-Crofts, Inc., New York, 1956. $4.50. Against a rich background of experience in research and teaching in child development, the author deals with exceptionally intelligent and talented children, the intellectually inadequate, children with speech defects, and the physically handicapped.

NEUTRAL CONTROL OF THE PITUITARY GLAND. By G. W. Harris. ix + 298 pp. The Williams and Wilkins Co., Baltimore, 1955. $6.75. A survey of current information on the hypophysis (pituitary, the "master gland"), designed for the advanced student. Last chapter deals with the effects of hormones on patterns of behavior.

CULTURE AND EXPERIENCE. By A. Irving Hallowell. xvi + 434 pp. University of Pennsylvania Press, Philadelphia, 1955. $7.00. An important publication of selected papers dealing with problems on the borderline between anthropology and psychology. Focussed on "conditions that make a human existence possible and which account for the distinctive quality of human experience."

INFANT NUTRITION IN THE SUBTROPICS AND TROPICS. By D. B. Jelliffe. 237 pp. World Health Organization, Geneva, 1955. $5.00. Following a review of infant-feeding practices, the author describes in detail the common nutritional diseases (including anemia, avitaminosis A, beriberi, rickets, and kwashiorkor) and methods of prevention. 28 pictures, 213 references.

SEXUAL PRECOCITY. By Hugh Jolly. xiii + 276 pp. Charles C. Thomas, Springfield, Ill., 1955. $6.75. A survey of 69 cases of sexual precocity, most of which fall into 3 etiological groups: "cerebral," adrenal, and gonadal. Typically, there is accelerated rate of skeletal growth but no precocity in dental growth or mental development.

NEBRASKA SYMPOSIUM ON MOTIVATION. Edited by Marshall R. Jones. x + 274 pp. University of Nebraska Press, Lincoln, 1955. $3.00 (paper), $3.50 (cloth). The third volume in the series *Current Theory and Research in Motivation* consists of 6 papers concerned with different aspects of the problem and different approaches to its study. J. Olds contributed a long paper on the physiological mechanisms of reward.

THE EFFECT OF SUGAR SUPPLEMENTS ON DENTAL CARIES IN CHILDREN. By J. D. King, May Mellanby, H. H. Stones, and H. N. Green. viii + 55 pp. Her Majesty's Stationery Office, London, 1955. (Available from the British Information Services, 30 Rockefeller Plaza, New York 20). $0.77. A report on 3 independent studies (in the London area, in Liverpool and in Sheffield). Conclusion: Substantial differences in sugar content of the diets had no significant effect on the initiation or spread of detal caries over periods of 1 to 2 years.

PSYCHOPHARMACOLOGY. Edited by Nathan S. Kline. x + 165 pp. The American Association for the Advancement of Science, Washington, 1956. $3.50. A symposium on the use of new pharmaceuticals, particularly chlorpromazine and reserpine, in the treatment of mental disease. These substances sedate the patient and allay his anxiety yet leave him conscious and amenable to psychotherapy. "New vistas are being opened for the psychiatrist, the neurologist, and physiologist, the pharmacologist, and the chemist" (W. Overholser, Foreword).

MIGRATION AND MENTAL DISEASE: A study of first admissions to hospitals for mental disease, New York, 1939-1941. By Benjamin Malzberg and Everett S. Lee. x + 142 pp. Social Science Research Council, New York, 1956. $1.50. The monograph is an important contribution to the analysis of complex interrelationships between migration and mental disease. Principal conclusions: 1) Rates of first admission were markedly higher for migrants, regardless of sex or color, and 2) the rates were much higher for recent than for earlier migrants. Extensive (42 pp.) introduction by Dorothy S. Thomas.

CURRENT TRENDS IN PSYCHOLOGY AND THE BEHAVIORAL SCIENCES. Edited by R. A. Patton. xvi + 142 pp. University of Pittsburgh Press, Pittsburgh, 1954. $4.00. This eighth volume in the *Current Trends in Psychology* series consists of an introduction by R. A. Patton, and 6 papers concerned —some more, some less directly—with the relationships between psychology and some of the other behavioral sciences, including anthropology and neurophysiology.

NUTRITION BIBLIOGRAPHY OF INDONESIA. By S. Postmus, R. Luyken, and P. J. Van der Rijst. ix + 135 pp. University of Hawaii Press, Honolulu, 1955. $1.75. An annotated bibliography of publications on foodstuffs, diets and nutrition (incl. some 70 entries on beriberi). A four-page glossary.

FAMILY AND FERTILITY IN PUERTO RICO. By J. Mayone Stycos. xv + 332 pp. Columbia University Press, New York, 1955. $6.00. "The first volume of the final report of the Family Life Research Project undertaken by the Social Science Research Center of the University of Puerto Rico with the purpose of trying to explain the dynamics of child spacing in Puerto Rican families of low income and low education."

THE PSYCHOLOGY OF HUMAN DIFFERENCES. By Leona E. Tyler. viii + 562 pp. Appleton-Century-Crofts, Inc., New York, 1956. $6.00. An up-to-date summary of the psychologists' substantial contribution to the study of human variability. Covers 1) individual differences in psychological variables, such as perception, intelligence and interests, 2) differences between groups, including age, sex, race, and class, and 3) factors producing the differences.

PRINCIPLES OF EMBRYOLOGY. By C. H. Waddington. x + 510 pp. The Macmillan Co., New York, 1956. $7.50. A textbook for students acquainted with the basic facts of comparative anatomy, useful to research workers in other branches of biology. Emphasis is placed on the experimental (causal) analysis rather than the descriptive account of developmental changes.

SOUTHERN AFRICA. Vol. II: Human Geography. By John H. Wellington, xviii + 283 pp. Cambridge University Press, New York, 1955. $6.50. Section 3, "The People," contains information on different segments (African, European, "Colored," Asian) of South African population, with emphasis on historical factors. A brief, final chapter is devoted to the physical and mental characteristics of the African.

BIBLIOGRAPHY OF MONOLINGUAL SCIENTIFIC AND TECHNICAL GLOSSARIES. By Eugen Wüster. 202 pp. UNESCO (Columbia University Press, New York), 1955. $2.50. Covers principally technology. A negligible number of entries concern biology directly (*nomina anatomica*, Hebrew psychological terms, malaria terminology).

JOSEF BROŽEK

University of Minnesota,
Minneapolis, Minnesota.

INFORMATION FOR CONTRIBUTORS

HUMAN BIOLOGY, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of 8½ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne State University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

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References in the text to the literature should be made by using the author's name followed by the year of publication: "Studies of Garn and Saalberg ('53) . . ." At the end of the article, under the heading "LITERATURE CITED," full references with titles and inclusive page references should appear (double spaced) in alphabetical order of the authors' names: "GARN, S. M. AND J. H. SAALBERG 1953 Sex and age differences in the composition of the adult leg. Human Biol., *25:* 144-153."

Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the proof has been returned to the press.

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a record of research

Volume 28 SEPTEMBER 1956 Number 3

CONTENTS

Body Composition in Childhood with Reference to *in vivo* Chemical Analysis of Water, Fat, and Protoplasmic Mass. *Icie G. Macy and Harriet J. Kelly* 289

Some Physical Peculiarities of Deaf-mute Boys. *Bin Yamaguchi* 309

The Relationship between the Occupational Status of Individuals and the Sex Ratio of their Offspring. *Harriett L. Fancher* 316

A Demographic Study of a Dinka Village. *D. F. Roberts* 323

Migration and Mental Disease in New York State, 1939-1941. *Benjamin Malzberg* 350

On Basic Principles in Dental Statistics. *Jaakko Kihlberg and Kalevi Koski* 365

Book Reviews 376

Book Notices 390

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THE INFLUENCE OF FOOD, BODY BUILD, AND SOCIAL ORIGIN ON THE AGE AT MENARCHE

BY LEA KRALJ-ČERČEK
Institute of Anthropology, University of Ljubljana, Yugoslavia

INTRODUCTION

IN girls, the first menstruation—menarche—is widely used as a criterion of sexual maturity, although it signifies neither the beginning nor the end of pubertal development.

The justification for the use of this criterion is the fact that ovulation or the formation and discharge of egg cells is closely connected—normally—with menstruation.

The wide range of variation in the age at menarche depends upon many factors. They are partly determined genetically, partly by the natural environment which acts upon the girl before menarche, especially climate and geographical location (Škerlj, '31 and '35; Wehefritz, '37; Gini and de Orchi, '39; etc.), and partly by factors to be found in the social environment.

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MATERIAL AND METHODS

The investigated material was collected from girls at two secondary schools and from acqaintances, all of whom were born in the north-eastern region of Slovenia (Styria) where they also lived the majority of the time from birth until menarche.

For 223 girls examined, I obtained the exact dates of their menarches and, consequently, I could determine the exact age at menarche in years, months, and days. A questionnaire was formulated following Professor Škerlj's advice.

For comparison, particulars of 52 girls from 10.0 to 24.9 years of age on the island of Susak near Lošinj in the northern Adriatic were gathered and treated in the same manner.

RESULTS

The Mean Age at menarche.

The minimum age at menarche in this group is 120 months (10.0 years) and the maximum, 207 months (17.25 years). The calculated mean value at menarche in this group is:

$$M \pm m_M = 13.61 \pm 0.83 \text{ years}$$
$$\sigma \pm m_\sigma = 1.23 \pm 0.59 \text{ years}$$

a value between the limits of $M \pm \sigma$ is considered typical, in this case 12.38 to 14.84 years of age. Within these limits are 181 individuals or 81.1%. (In a completely normal distribution, 68.26% of all occurrences would be expected within these limits.)

The mean age at menarche of the present group is two months higher than the value ($M = 13.43$) obtained by Škerlj ('40) from 591 Slovenian secondary school girls. One of the reasons for this difference is probably that menarche occurs sooner in urban than rural areas. Perhaps the same reason accounts also for the later onset of menarche on the island of Susak, though one must not exclude other factors (low hygienic and bad social conditions, etc.), which very probably influence menarche. The mean age at menarche of 52 girls from the island of Susak is:

$$M \pm m_M = 13.94 \pm 0.17 \text{ years}$$
$$\sigma \pm m_\sigma = 1.235 \pm 0.122 \text{ years.}$$

The mean is 3.96 months higher than the mean for Styrian girls,

TABLE 1

The distribution according to the age at which menarche occurs, in months

AGE OF THE GIRL AT THE MENARCHE CALCULATED TO NEAREST MONTH	NUMBER OF GIRLS	AGE OF THE GIRL AT THE MENARCHE CALCULATED TO NEAREST MONTH	NUMBER OF GIRLS
120	1	165	3
123	1	166	6
129	1	167	8
132	3	168	16
133	2	169	6
136	1	170	4
140	2	171	5
142	3	172	4
143	1	173	6
144	6	174	6
146	3	175	3
148	6	176	2
149	3	177	4
150	5	178	3
151	3	179	2
152	5	180	5
153	3	181	3
154	4	182	3
155	2	183	1
156	18	187	2
157	9	188	1
158	4	189	1
159	10	190	1
160	8	191	1
161	4	192	4
162	4	202	1
163	4	207	1
164	2		
		Total........................	223

and 6.16 months higher than the mean ($M = 13.43$ years) found by Škerlj for secondary school girls in Ljubljana. Gound and Gould (cited after Hurlock, '49) found for a group of 680 girls at Louisiana State College exactly the same mean value ($M = 13.61$ years) which was calculated for our 223 Styrian girls.

TABLE 2

Accommodation of the distribution in years to the normal curve

CENTERED CLASSES IN YEARS	DIFFERENCE BETWEEN THE CENTERED CLASSES AND THE ARITHMETIC MEAN	RELATION BETWEEN THE DIF. (COLUMN 2) TO σ	ORDINATE AT x/σ	THEORETICAL FREQUENCY	OBSERVED FREQUENCY	DIFFERENCE BETWEEN THEORETICAL AND OBSERVED FREQUENCY	THE SQUARE OF THE DIFFERENCE BETWEEN THEORETICAL AND OBSERVED FREQUENCIES	AVERAGES OF THE SQUARE DIFFERENCE BETWEEN THEORETICAL AND OBSERVED FREQUENCIES
$\bar{X}$	$\bar{X} - M = x$	x/σ	a	$a \cdot \frac{N}{\sigma} = m$	m'	$m' - m$	$(m' - m)^2$	$\frac{(m' - m)^2}{m}$
10.5	—3.11	2.53	0.0163	2.96	4	—3.50	10.22	0.64
11.5	—2.11	1.72	0.0909	16.54	12			
12.5	—1.11	0.95	0.2541	46.25	40	—6.25	39.0	0.84
13.5	—0.11	0.09	0.3973	72.31	80	7.69	59.0	0.82
14.5	0.89	0.73	0.3056	55.62	61	5.38	29.0	0.52
15.5	1.89	1.54	0.1219	22.19	18			
16.5	2.89	2.35	0.0252	4.59	7	—1.27	1.62	0.063
17.5	3.89	3.16	0.0027	0.49	1			
Totals	. . . .			220.95	223			2.883

$\chi^2 = 2.883$, with 4 degrees of freedom $P = .58$

Using the equation $y = 72.6xe^{-\frac{1}{2}\cdot X^2/1.5129}$, graph 1 shows the normal curve, the frequency distribution polygon, and the integral curve. The comparison of the polygon with the normal curve shows a good fit which is also confirmed by the theoretical curve on which the sums of the observed frequencies are distributed.

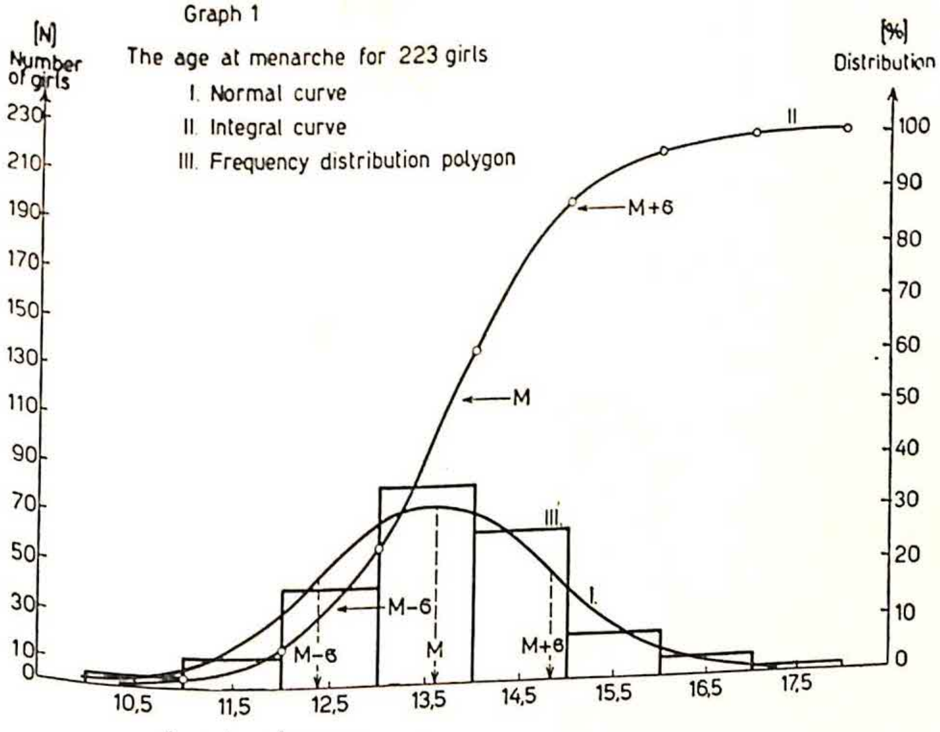

FIGURE 1.

Graph 2 represent the integral curve on Hazen's probability logarithmic paper, where the theoretical integral curve is a straight line, from which the probability of menarche in the group can be estimated to one-tenth of a year.

Influence of nutrition on the age at menarche.

As shown by Škerlj ('47) the age at menarche depends on the type of nutrition the girl had before menarche. To investigate the influence of nutrition, the 223 girls from northeastern Slovenia (Styria) and the 52 from the island of Susak were classified according to their nutrition into the following groups: proteinous, mixed, and carbohydratic.

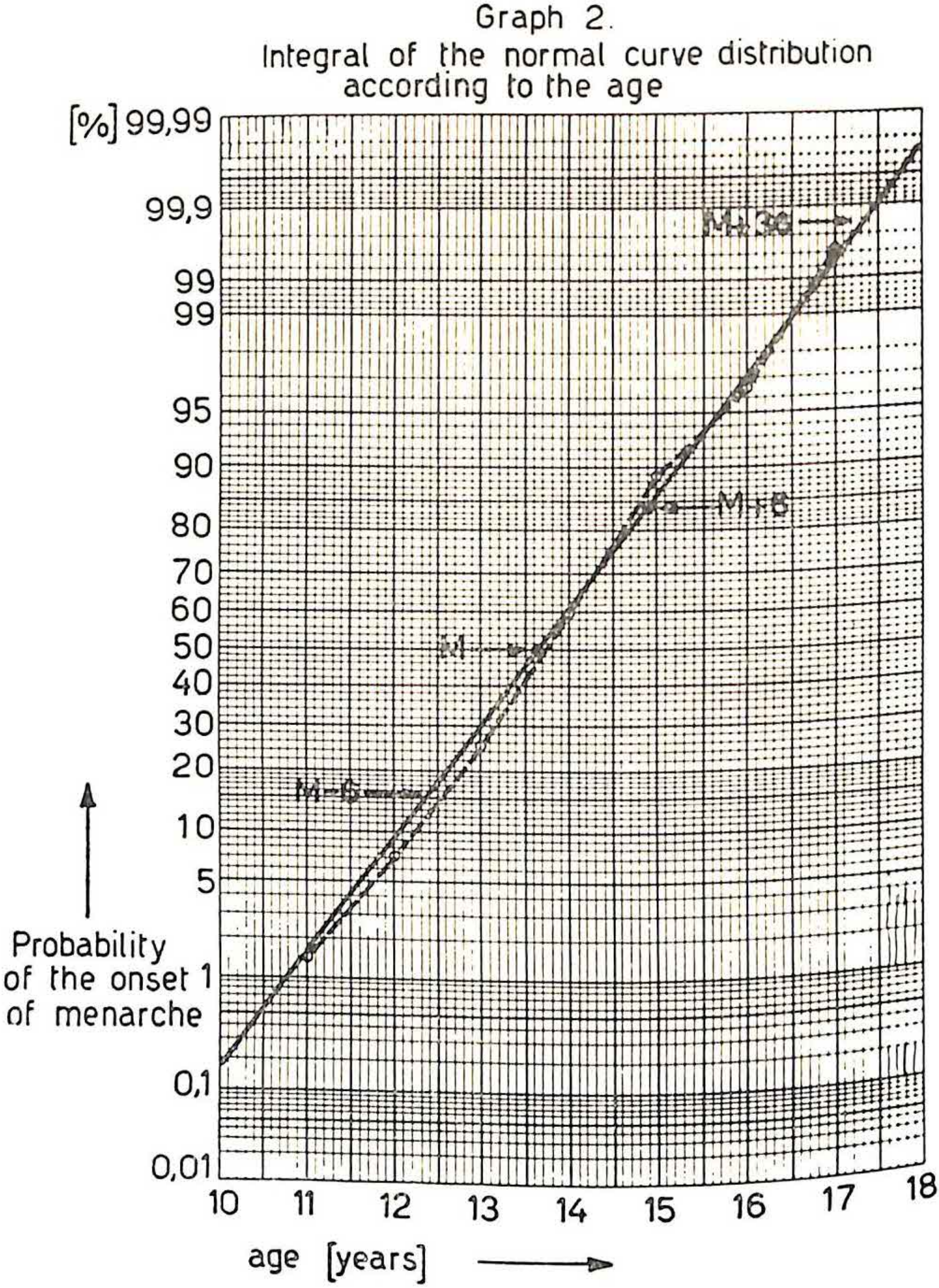
Graph 2.
Integral of the normal curve distribution according to the age
[%]
99,99
99,9
99
99
95
90
80
70
60
50
40
30
20
10
5
1
0,1
0,01
Probability of the onset of menarche
M+3σ
M+σ
M
M-σ
10
11
12
13
14
15
16
17
18
age [years]

FIGURE 2.

The type of nourishment was marked on the form in answer to the questions and the girls' own classifications.

Among 223 girls, 45 ate proteinous, 75 mixed, and 103 predominantly carbohydratic food. The characteristics in table 3 show that the girls who ate predominantly proteinous food had their menarche sooner than girls who ate mixed, whereas those who ate carbohydratic food menstruated latest. The results are in accordance with Škerlj's assumption, that proteinous food has an influence on earlier menarche.[1]

The differences between the single groups are without a doubt characteristic since the "t" scores of the differences between the single groups, especially between the two extreme ones, are statistically significant.

Proteinous to mixed food: $t_D = 3.87$

Mixed to carbohydratic food: $t_D = 3.59$

Proteinous to carbohydratic food: $t_D = 8.13$.

TABLE 3

Characteristics of the age at menarche, in years, of the Slovenian girls, according to the kind of nutrition

PROTEINOUS	MIXED	CARBOHYDRATIC
number = 45	number = 75	number = 103
$M \pm m_M = 12.65 \pm 0.133$	$M \pm m_M = 13.42 \pm 0.145$	$M \pm m_M = 14.1 \pm 0.111$
$\sigma \pm m_\sigma = 0.88 \pm 0.094$	$\sigma \pm m_\sigma = 1.25 \pm 0.104$	$\sigma \pm m_\sigma = 1.6 \pm 0.080$

TABLE 4

Characteristics of the age at menarche, in years, of the Susak girls according to the kind of nutrition

PROTEINOUS	MIXED	CARBOHYDRATIC
number = 10	number = 17	number = 25
$M \pm m_M = 12.9 \pm 0.237$	$M \pm m_M = 14.1 \pm 0.297$	$M \pm m_M = 14.2 \pm 0.237$
$\sigma \pm m_\sigma = 0.73 \pm 0.163$	$\sigma \pm m_\sigma = 1.22 \pm 0.208$	$\sigma \pm m_\sigma = 1.15 \pm 0.163$

By using the same method of investigation, similar results (table 4) were obtained for 52 girls of the island of Susak.

---

[1] Škerlj classified the girls according to the weekly and daily frequencies of meat eaten. Girls who ate meat at least 7 times a week had their menarche at 12.83 ± 0.61, those who ate meat twice a day at 11.7 ± 0.74, whereas girls who ate meat only once a week had their menarche at 14.10 ± 0.25 years.

Menarche and body build.

An interesting factor is the girl's body build in relation to menarche. The girls were classified visually during gymnastic classes when they wore gym clothing:

1. Baroque: "pyknic," broad body build, feminine
2. Renaissance: "medium"
3. Gothic: "linear" or "boyish" type, angular

The mean values and other statistical characteristics are presented in table 5 from which it is evident that girls of the baroque type menstruate earlier than girls of the renaissance type, whereas the gothic type have the latest menarche.

TABLE 5

Age in years at menarche in relation to body-build of 223 girls

BAROQUE TYPE	RENAISSANCE TYPE	GOTHIC TYPE
number = 69	number = 97	number = 57
$M \pm m_M = 12.93 \pm 0.222$	$M \pm m_M = 13.5 \pm 0.104$	$M \pm m_M = 14.61 \pm 0.134$
$\sigma \pm m_\sigma = 1.29 \pm 0.089$	$\sigma \pm m_\sigma = 0.96 \pm 0.073$	$\sigma \pm m_\sigma = 0.95 \pm 0.089$

The difference between the single groups, especially between extreme groups, are statistically significant as shown by the following "*t*" scores:

Baroque to Renaissance type: $t_D = 2.33$
Renaissance to Gothic type: $t_D = 6.34$
Gothic to Baroque type: $t_D = 6.38$.

Škerlj *et al.* ('53) found in 1,709 girls that the "pyknic" or fat ones have the earliest menarche ($M = 12.99$ years) and that the leptosomatic girls ($M = 13.50$ years) mature later than the eurysomatic ones ($M = 13.36$ years). The medium ones, of "normo-type" mature the latest ($M = 13.66$ years). By comparing the values in table 5 with those of Škerlj it is evident that only the mean values for the pyknic type correspond. The reason for the difference in other types probably is the different method of body-typing.

On the island of Susak, girls are maturing according to their respective body build in the same order: 14 girls of the baroque type had their menarche at 13.40 ± 0.267 years; 21 girls of the medium type at 14.05 ± 0.252 years, and 17 girls of the gothic type at 14.3 ± 0.326 years.

The differences are not as large as the mainland group but in spite of this, the "*t*" score between the two extreme groups is statistically significant:

baroque to gothic type: $t_D = 2.14$.

Influence of social origin.

The results, achieved by investigating the influence of social origin on the age at menarche, are in accordance with the findings of several authors (Škerlj, '50; Peller and Zimmermann, '32; Schreiner, '22; and others).

From the answers of the 223 girls and from my estimation according to the parents' vocations, the social enviroment was classified. The girls of good social origin had their menarche first, then the intermediate, and last the poor group.

TABLE 6

Age in years at menarche in relation to social status of 223 girls

GOOD	MEDIUM	POOR
number = 80	number = 123	number = 20
$M \pm m_M = 13.28 \pm 0.134$	$M \pm m_M = 13.71 \pm 0.104$	$M \pm m_M = 14.2 \pm 0.282$
$\sigma \pm m_\sigma = 1.195 \pm 0.089$	$\sigma \pm m_\sigma = 1.22 \pm 0.073$	$\sigma \pm m_\sigma = 1.24 \pm 0.193$

The "*t*" scores for the differences between the single groups are:

Good to medium social status: $t_D = 2.54$

Medium to poor social status: $t_D = 1.50$

Good to poor social status: $t_D = 2.51$.

The influence of social origin is evident also in the group of girls from the island of Susak. The differences between the single groups are, in spite of the small number, greater than those between the single groups presented in table 6. The "*t*" score for the difference between the good ($M = 12.9$ years) and medium ($M = 13.77$ years) group is $t_D = 2.67$, between medium and poor ($M = 14.5$ years) is $t_D = 2.25$, and between good and poor is $t_D = 5.08$.

Interestingly enough, it is impossible to claim that the social status good corresponds to the proteinous, the medium to the mixed, and the poor to the carbohydratic nutrition; contrary to this, the type of nutrition is more or less uniformly distributed among the groups good, medium, and poor. Within the good group 25% of the girls ate proteinous, 32.5% mixed, and 42.5% carbohydratic food. In the medium group 22.4% of the girls ate proteinous, 27.8% mixed, and 49.8% carbohydratic food. In the poor group 25% of the girls ate proteinous, 25% mixed, and 50% carbohydratic food.

Consequently, one has to investigate the influence of social origin on the age at menarche as a separate factor and not identify the social origin with the kind of nutrition.

DISCUSSION

From the preceding, it is evident that various environmental factors, natural as well as social, influence the age at the menarche: nutrition, social conditions, and what may be called (with some reservation) "body build." If we were to investigate the influence of only one of these factors to estimate its "weight," we would have to eliminate all the others. If we do not do this, we negate the factors the influence of which we already admitted as proved.

The mean age at menarche (SM) may be presented as a mathematical function of the single parameters:

$$SM = f/O_k; (p, m, o); (b, r, g); (A, B, C); X/$$

O_k = influence of natural environment
p = proteinous food
m = mixed food
o = carbohydratic food
A = social status good
B = social status medium
C = social status poor

b = baroque type
r = renaissance type
g = gothic type
X = all up to the present unknown or unexplained factors, which should be put into the formula.

Since each girl within the investigated group ate more or less specifically one of the basic kinds of food, belonged to a distinct somatotype, and lived in a good, medium, or poor social condition, consequently, to investigate the dependence of the age at menarche on any one of the parameters, it would be mathematically incorrect not to fix all the others. Investigating the absolute "weight" of the effect of nutrition. I find the solution of this function would be generally the following:

1. $SM' = f/(p);(b);(A)/$
$$m = 0; o = 0; r = 0; g = 0; B = 0; C = 0;$$
2. $SM'' = f/(m);(b);(A)/$
$$p = 0; o = 0; r = 0; g = 0; B = 0; C = 0;$$
3. $SM''' = f/(o);(b);(A)/$
$$p = 0; m = 0; r = 0; g = 0; B = 0; C = 0;$$

Since the entire group is from the same region (Styria), O_k is fixed; therefore, this factor has the same "weight" of effect on all the results: consequently, O_k is itself eliminated in the search for the differences between SM', SM'', SM''', *i.e.*, $O_k = 0$.

For the time being, the same may be assumed for the parameter X.

$SM'' - SM' = d_1$
$SM''' - SM'' = d_2$
$SM''' - SM' = d_3$

$d_1 =$ difference due to the different influence of proteinous and mixed nutrition;
$d_2 =$ difference due to the different influence of mixed and carbohydratic nutrition;
$d_3 =$ difference due to the different influence of proteinous and carbohydratic nutrition.

Similarly the "absolute weight" of the influence of all other parameters could be obtained; there is a large number of possible combinations.

If we do not fix primarily the influence of nourishment, an error results from the effect of nutrition when investigating the body build's influence, which is shown in figure 3.

In the group of 233 girls from northeastern Slovenia differences already arise if we investigate the influence of the different kinds of nutrition within the group of girls of equal body build without respect to the social status to which the girls belong.: This may be seen from the results in table 7 in which, within the three fixed basic kinds of food, the influence of body build is to be found, and conversely.

The "t" scores of differences between the extremes confirm that these differences are statistically significant.

The "t" scores of differences between the extreme groups are:

$b_p - b_o:\ t_D = 3.54$
$r_p - r_o:\ t_D = 4.05$
$g_p - g_o:\ t_D = 7.43$

$p_b - p_g:\ t_D = 6.45$
$m_b - m_g:\ t_D = 6.64$
$o_b - o_g:\ t_D = 2.18$

TABLE 7

TYPE	PROTEINOUS	MIXED	CARBOHYDRATIC
Baroque	$M \pm m_M = 12.42 \pm 0.178$ years $\sigma \pm m_\sigma = 0.91 \pm 0.134$ years	$M \pm m_M = 12.45 \pm 0.208$ years $\sigma \pm m_\sigma = 0.91 \pm 0.134$ years	$M \pm m_M = 13.86 \pm 0.356$ years $\sigma \pm m_\sigma = 1.45 \pm 0.193$ years
Renaissance	$M \pm m_M = 12.87 \pm 0.193$ years $\sigma \pm m_\sigma = 0.77 \pm 0.134$ years	$M \pm m_M = 13.47 \pm 0.178$ years $\sigma \pm m_\sigma = 1.08 \pm 0.119$ years	$M \pm m_M = 13.79 \pm 0.119$ years $\sigma \pm m_\sigma = 0.77 \pm 0.089$ years
Gothic	$M \pm m_M = 13.6 \pm 0.000$ years $\sigma \pm m_\sigma = 0.0 \pm 0.000$ years	$M \pm m_M = 14.51 \pm 0.237$ years $\sigma \pm m_\sigma = 0.95 \pm 0.163$ years	$M \pm m_M = 14.7 \pm 0.148$ years $\sigma \pm m_\sigma = 0.93 \pm 0.104$ years

Since the intention of this paper is not to investigate the whole function, the possibilities and meaning of such a treatment has been shown by these examples. In considering the social status also, the parameters could have been arranged according to their "weight" of influence on the age at menarche.

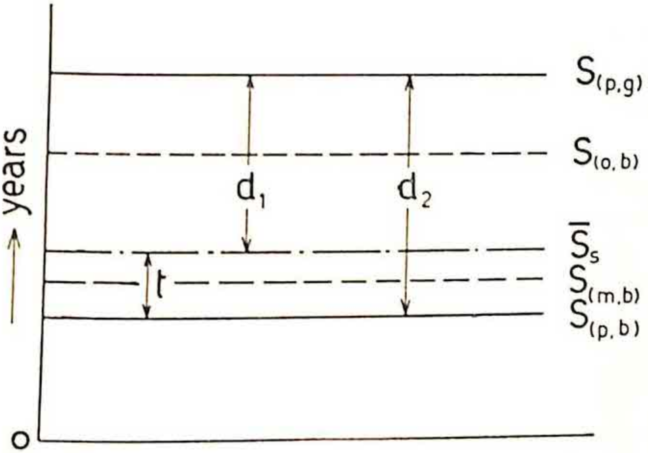

FIGURE 3. SCHEME SHOWING INFLUENCE OF NUTRITION ON ESTIMATION OF AGE AT MENARCHE ACCORDING TO BODY TYPE.

d_1 = difference in years between $S_{(p.g)}$, representing the mean value for the proteinous food for the gothic girls

S_s = the mean value resulting from the mean values of the sum:

$S_{(o.b)}$ = carbohydratic nutrition of the baroque type,

$S_{(m.b)}$ = mixed nutrition of the baroque type, and

$S_{(p.b)}$ = proteinous nutrition of the baroque type

d_2 = difference in years between $S_{(p.b)}$ and $S_{(p.g)}$, resulting only from the different types (baroque-gothic)

$d_2 - d_1 = \pm t$: error resulting from the influence of nutrition

CONCLUSIONS

The mean age at menarche of 223 secondary school girls in north-eastern Slovenia is 13.61 ± 0.83 years. It ranges from 10.0 to 17.25 years. Typically, these girls have their menarche between the age of 12 years and 4.6 months to 14 years and 10 months.

Nutrition markedly influences the rate of maturation; proteinous food accelerates, while carbohydratic nutrition inhibits the process. Former investigations of the hormonal glands show a close connection in the activity of the anterior lobe of the pituitary gland with sexual glands. As known, the anterior lobe of the pituitary gland produces, among others, gonadotropical hormones which affect the sexual glands and stimulate them to increased activity. Up to the present there is no satisfactory explanation for the causes of the increased production in gonadotropic hormones and the sensitivity of the gonads for these hormones in a more or less specific period during puberty. Perhaps just the influence of nutrition, which may be an activator or inhibitor, may explain the above question on maturation. Only more extensive investigations of the endocrine glands by experimentation could perhaps give a satisfactory solution.

The results also show that body build has an influence on the age at menarche. Furthermore, the influence of social origin has been confirmed.

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COMPARISON OF PINCH-CALIPER AND TELEROENTGENOGRAMMETRIC MEASUREMENTS OF SUBCUTANEOUS FAT[1]

BY STANLEY MARION GARN AND EDWARD L. GORMAN
Fels Research Institute, Antioch College
Yellow Springs, Ohio

INTRODUCTION

THE roentgenogrammetric and the pinch-caliper techniques of subcutaneous fat measurement are two presently competitive methods, each with its own particular advantages. The pinch-calipers are portable, self-contained and suitable for field use, but they compress the tissues to a still undetermined extent. Teleroentgenograms, on the other hand, permit the measurement of uncompressed single skin-plus-fat thicknesses, often at sites unsuitable for pinching, but the necessary apparatus is not always available (cf. Brožek and Keys, '50; Keys and Brožek, '53).

Since both of these techniques are used, and will continue to be used, it is of interest to determine first how well the results agree, and second, the extent to which the double fold is compressed, in reference to the uncompressed single thickness measured on teleroentgenograms. The present study, conducted on a selected sample of males with a narrow age range, and at a site ideal for both techniques, provides preliminary answers to both questions.

METHODS AND MATERIALS

Roentgenograms were taken and pinch-caliper measurements made on a total of 65 young adult males, all students at Antioch College. The age range was 21.0 to 22.9 years, and the weight range was 54 to 95 kg.

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[1] The present study was supported in part by Contract 18(600)1566 with the Air Research and Development Command.

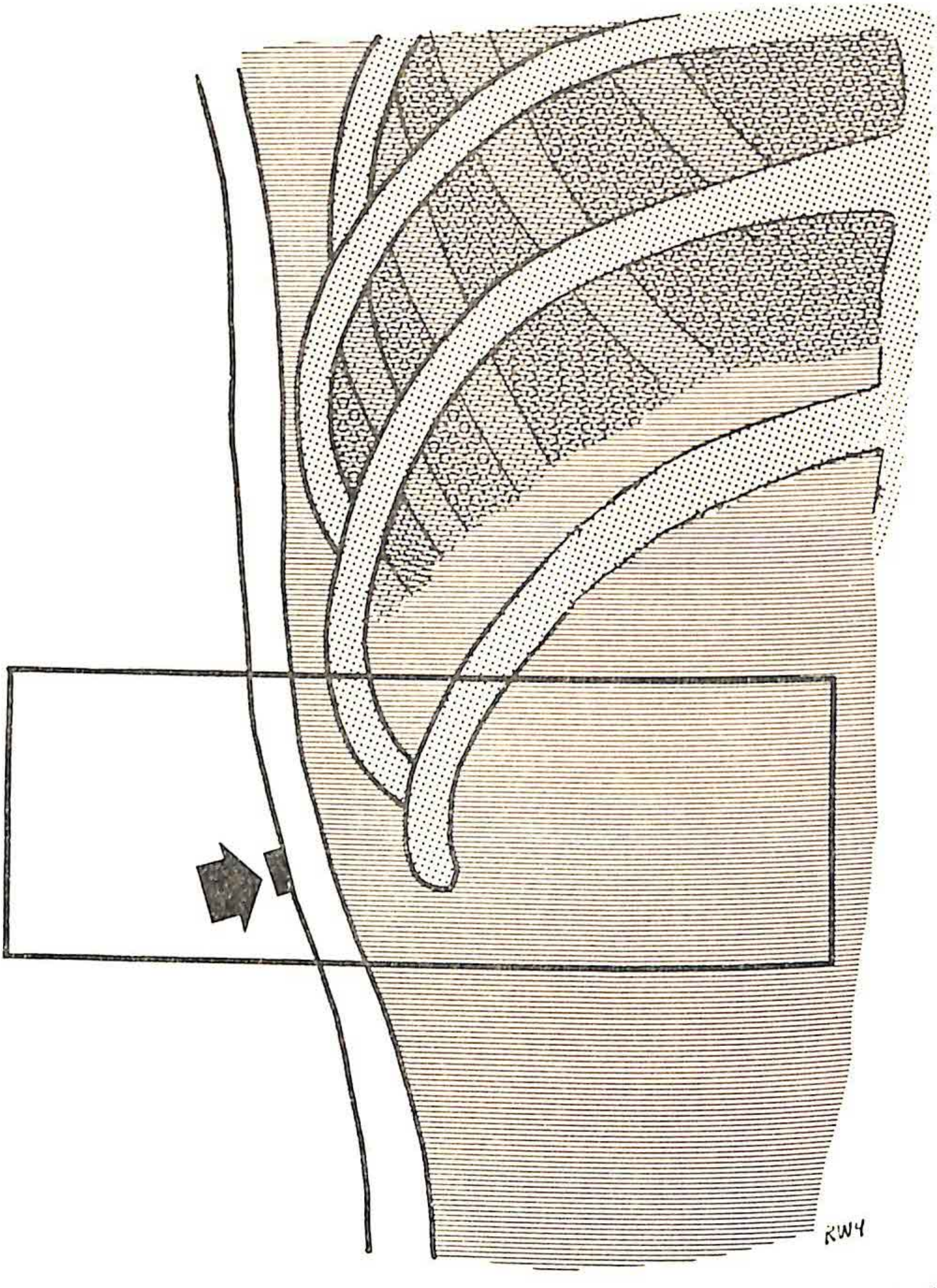

FIG. 1. The lateral thoracic section, traced from a postero-anterior chest roentgenogram, and showing (in the rectangular enclosure) the area actually included. The arrow points to the lead indexing dot, and to the skin-plus-fat thickness measured.

At the time of examination, the lower border of the left rib cage was located by palpation, and marked by a lead-rubber dot affixed at this level, but at the mid-axillary line. Then a true postero-anterior teleroentgenogram was taken of this section, with the central ray directed to the indexing dot. Finally, the lead-rubber dot was removed, and a double fat-fold measured, using a spring-loaded caliper equipped with jaws 30 square millimeters in area, and exerting a constant pressure of 10 grams per square millimeter.[2] The site measured, which is designated as "lower thoracic," apparently corresponds to chest site no. 4 pictured by Edwards ('50). It is close to the "waist" measurement (no. 5) used by Škerlj *et al.* ('53, p. 580) but is well removed from the chest-fat measurement employed by Newman ('52).

The thickness of a single fat-plus-skin layer was measured at the indicated point on the radiographs at right angles to the skin surface, using a vernier micrometer with ground tips (Garn and Saalberg, '53). Details of the radiographic and roentgenogrammetric procedure otherwise follow Garn ('54). The location of the measurement (lower thoracic fat) is shown in fig. 1, which is a tracing of an x-ray section used in the present study.

FINDINGS

As shown in fig. 2, the two sets of measurements exhibit a fairly high degree of correlation ($r = 0.88$), and the relationship between the two appears to be reasonably linear, since the correlation ratio (ρ) is not notably higher than the product moment correlation (r). The roentgenogrammetric single-thickness measurements and the pinch-caliper double-thickness measurements both exhibit moderate correlations with weight ($r = 0.58$ and 0.48 respectively). Both techniques appear to provide equally good indications of body fat.

Analyses of the two distributions show them to be comparable in form. As would be expected, both are highly skewed, with a long tail to the right. The Pearsonian coefficient of skewness (SK) is 0.86 for the roentgenogrammetric measurements, and 0.79 for the pinch-caliper measurements. The pinch-caliper measurements are somewhat larger (median 12.0, mean 13.9) than the x-ray measurements (median 9.3, mean 11.1).

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[2] The pinch-calipers used were constructed by the Yellow Springs Instrument Company, and were modified from a design by the Laboratory of Physiological Hygiene, University of Minnesota. Dr. Brožek's recommendations on jaw area and pressure were followed.

Since the pinch-caliper measurements are considered to represent a compressed *double* fold, it is therefore necessary to compare these values with twice the uncompressed value as computed from the means. The pinch-caliper values average 63% of the theoretical uncompressed double thickness while the median is 65% of the theoretical uncompressed double thickness. Corrected for x-ray enlargement (due to divergence of rays), the pinch-caliper values thus average approximately 70% of their true uncompressed thickness along the full scale.

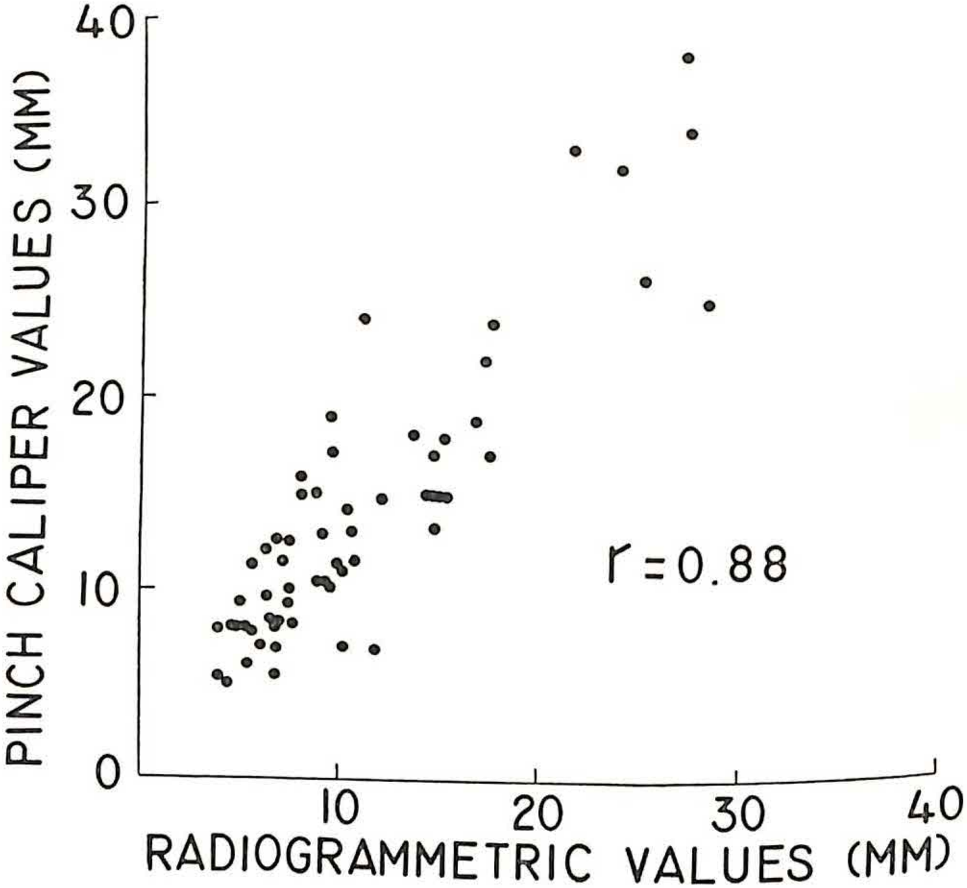

FIG. 2. Scattergram showing the relationship between the teleroentgenogrammetric measurements (abscissa), and the pinch-caliper measurements (ordinate) of the lower thoracic fat. For 65 young adult males aged 21–22 years, the obtained r is 0.88.

Assuming then, that there is a 30% reduction in thickness due to compression, the corrected pinch-caliper measurements, and the computed theoretical double folds closely agree. Apparently the percentage reduction is consistent in the range 6–60 mm as shown in table 1.[1]

The closeness of the two distributions is further shown by the high degree of correspondence between paired values. The mean difference was 0.2 mm with a standard deviation of 1.1 mm. The largest discrepancy between an observed and "calculated" double-fold was 3.8 mm.

TABLE 1

Comparison of corrected pinch-caliper values with true double-fold thickness

CLASS INTERVAL (MM)	TRUE DOUBLE-FOLD THICKNESSES [1] No.	%	CORRECTED PINCH-CALIPER THICKNESSES [1] No.	%
0– 5.9	0	0.0	0	0.0
6–11.9	11	18.0	8	13.1
12–17.9	17	27.9	22	36.1
18–23.9	13	21.3	14	23.0
24–29.9	5	8.2	8	13.1
30–35.9	9	14.8	1	1.6
36–41.9	0	0.0	4	6.6
42–47.9	1	1.6	0	0.0
48–53.9	2	3.3	3	4.9
54–59.9	3	4.9	1	1.6
60–65.9	0	0.0	0	0.0

[1] Roentgenogrammetric values × 2.0, Pinch-caliper values × 1.54
Medians 18.6 and 18.6 mm respectively.

DISCUSSION

It is evident from these findings that the two techniques compared here agree surprisingly well, thus confirming Baker's findings which relate to leg and arm fat thickness (Baker, '55). In fact, the true correlation in the present study may be expected to exceed 0.90 or even 0.95, since attenuation was not taken into account. Naturally, comparable degrees of agreement should not be expected for dorsal or ventral sites (which are less easily measured on teleroentgenograms), or pelvic sections where the subcutaneous tissue is firmly attached to the deep fascia (*cf.* Edwards, '50, p. 260). The lower thoracic site was specifically selected for study, because it pinched well and x-rayed well (Garn, '56).

Clearly, pinch-caliper measurements at this site, where the underlying fat is rather loosely structured, fall short of the calculated true or uncompressed double-fold. At 10 grams/mm^2 pressure, with a 30 mm^2 jaw area, the 300 gram force reduces the double fold approximately 30% along the full range of thicknesses encountered. Similar results were obtained, using a slightly different pinch-caliper on 20 of the 65 subjects, indicating that the exact form of the instrument is not a determining variable.

Practically, then, pinch-calipers may be substituted for radiographs, if the lower thoracic section is measured, and if the results are utilized on a group basis. Further, pinch-caliper thicknesses may be corrected to uncompressed values, or made comparable to single uncompressed thicknesses, by applying the proper constant. Additional studies are necessary, however, before these findings can be applied to other fat sites, and to other age groups, and especially to grossly obese individuals where uncompresed lower thoracic fat thicknesses may exceed 60 mm, and even more.

SUMMARY

1. Roentgenogrammetric and pinch-caliper measurements of the fat-plus-skin thickness at the lower thoracic region at the mid-axillary line were compared.

2. For 65 young adult males, aged 21 and 22 years, the correlation between the two sets of measurements was 0.88.

3. While the two distributions were of comparable form and degree of skewness, the "double skinfolds" averaged 70% of their calculated true value, indicating 30% reduction due to tissue compression under a total force of 300 grams.

ACKNOWLEDGMENTS

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HYPERTROPHIC PYLORIC STENOSIS IN THE SOUTH AFRICAN BANTU

BY JOAN GRIFFITHS

Pediatric Registrar, University of the Witwatersrand and Baragwanath Hospital, Johannesburg, South Africa

THE finding of what is believed to be the first reported case of hypertrophic pyloric stenosis in a South African (Negro) infant raised the question whether an analysis of this condition in Negroes might cast light on its etiology. Emotional and environmental factors may be significant in the etiology of a condition rare in African as compared with American Negroes.

THE CASE

A typical case of hypertrophic pyloric stenosis in a one month old male Bantu infant was seen in September, 1954. His mother was of the Moroleng tribe, his father a Xosa. The diagnosis was confirmed at operation. Incidentally, the mother had been much worried throughout the pregnancy and post-partum period.

THE INCIDENCE OF HYPERTROPHIC PYLORIC STENOSIS IN JOHANNESBURG

Since this is the first reported case in a full blooded Bantu, and the disease appears to be so rare among non-white South Africans, an attempt was made to determine its incidence among all races in Johannesburg.

Table 1 shows the incidence of pyloric stenosis among Europeans and non-Europeans admitted to hospital. For non-Europeans there are few other hospital facilities, and it can be expected that nearly all cases reach the two hospitals shown. However, for Europeans there are many private nursing homes, and the number of cases shown in table 1

TABLE 1

The incidence of pyloric stenosis in Johannesburg in 1954 among children in hospital

HOSPITAL	TOTAL ADMISSIONS	NO. OF CASES	CASES PER 1,000 ADMISSIONS
Transvaal (European) Memorial Hospital	4,029	14	3.47
Baragwanath Non-European Hospital	4,922	2	0.41
Coronation Non-European Hospital	2,211	1	0.45

is probably lower than the true incidence among hospitalised European children. The number of cases seen in 1954 at the Transvaal Memorial Hospital was lower than in preceding years: in 1952 there were 17 cases and in 1953, 19 cases.

The two cases seen at Baragwanath Hospital were both proved at operation; one was Bantu and the other of mixed racial origin. Symptoms suggestive of pyloric stenosis were seldom seen in the 64,000 out-patient visits made to the hospital by children in 1954. The single case seen at Coronation Hospital was Bantu and was treated medically.

TABLE 2

Births and infantile deaths and incidence of pyloric stenosis in Johannesburg in 1953-1954 *

RACE	NO. OF REGISTERED BIRTHS JULY 1953 TO JUNE 1954	HOSPITAL CASES OF PYLORIC STENOSIS JULY 1953 TO JUNE 1954	NO. OF REGISTERED INFANTILE DEATHS 1953-1954	NO. OF DEATHS DUE TO PYLORIC STENOSIS 1953-1954
European	8,570	11	253	2
Eurafrican and Asiatic	2,456	1	164	1
Bantu	12,580	0	1,778	—

* The period covered by this table differs from that in table 1.

This hospital serves more Eurafricans and Asiatic patients than Baragwanath and has previously seen two or three cases of pyloric stenosis yearly, but the patients were not pure Bantu. The two Bantu cases for 1954 were the first ever seen at these Johannesburg hospitals.

The number of deaths shown in table 2 represent death certificate notifications. None of the hospital cases died, so the deaths due to pyloric stenosis represent additional cases. This table again demonstrates the rarity of pyloric stenosis among the Bantu.

DISCUSSION

The incidence of pyloric stenosis in the South African urban Bantu appears to be very low. Are cases being missed? It is realised that the recorded incidence of pyloric stenosis of infancy rises with the standard of medicine practised in the area. In Johannesburg, medical services for the Bantu are sufficiently developed to prevent many cases from being missed. The city contains a university medical school and three teaching hospitals. Baragwanath hospital provides radiological and laboratory facilities and has 7 specialist pediatricians in full-time employment. It is known that Bantu mothers readily avail themselves of the services provided by hospitals and clinics (Higginson *et al.*, '54) and 54% of registered Bantu births attend infant welfare clinics provided by the City Health Department, where qualified Health Visitors and Child Welfare Medical officers are employed (Griffiths, '54).

The incidence of pyloric stenosis in England, according to Davison ('46) is three cases per 1,000 children born, and in Gotëberg in Sweden Wallgren ('41) found one case per 250 births. On the basis of these figures Bantu cases should number at least 37 to 50.

In Johannesburg amongst whites the incidence of pyloric stenosis is probably similar to Davison's English figures. The number of cases for the year recorded in table 2 is 13, whereas the expected number is approximately 25. This is almost certainly due to the fact that cases were seen by private practitioners and not admitted to public hospitals, especially as in Johannesburg medical rather than surgical treatment is favoured among some pediatricians.

The hospital incidence overseas is very much higher than the Bantu hospital incidence, but similar to the city's European incidence, as in the Milwaukee Children's Hospital, where one in 213 admissions had pyloric stenosis (Schaefer and Erbes, '48). In Edinburgh, at the Royal

Hospital for Sick Children, the incidence is even higher than this with 13.7 cases per 1,000 admissions in 1951 (Nicholson, '53).

Is the low incidence in the Bantu a characteristic of negroid races? It would appear that pyloric stenosis is now more frequent in American Negroes than it used to be.

Ward ('27) reviewing the literature, found no cases amongst them before 1927. Bakwin in 1932 stated that pyloric stenosis was rare in Negroes. However, from 1916 to 1936 at the Charity Hospital for New Orleans, 30% of 76 cases were Negroes, although this figure was a little lower than might have been expected for the number of Negroes amongst general admissions to the hospital (Romano and McFetridge, '38). At the Boston City Hospital, of 41 cases submitted to operation between 1949 and 1952, 8 were Negro children (English *et al.*, '54).

American Negroes do not trace their ancestry to the same part of Africa as those of Johannesburg, among whom, as previously noted, pyloric stenosis is rare. However, in other parts of Africa such as Rhodesia (Gelfand, '48) and Belgian Congo (Wallgren, '41) the condition is also apparently seldom seen. In Rhodesia Shepherd-Wilson and Gelfand ('55) published an account of the first case which they had seen in an African infant. Their patient was admitted in October, 1954, and the diagnosis confirmed at operation.

If the figures for American Negroes reflect a true increase in the incidence of pyloric stenosis, the question arises as to whether environmental factors may be responsible. There is already evidence that psycho-somatic factors play a part in pyloric stenosis. Powers ('53) surveyed the emotional background of pregnant and parturient mothers of infants with pyloric stenosis, chosen at random over a 10 year period. He found that the majority of the mothers were nervous or tense during the pregnancy and immediate post-partum period. However, his survey was small, and apparently without controls.

Sontag ('41) stated he had observed a relationship between pre-natal stimulation and some of the early feeding difficulties of infants. He suggested that prolonged nervous and emotional disturbances of the pregnant mother might produce an irritable and hyperactive autonomic nervous system in the foetus.

A follow-up study on individuals who suffered from hypertrophic pyloric stenosis in their infancy showed a high incidence of peptic ulcer, ulcerative colitis and highly strung, unstable personalities (Bendix and Necheles, '47).

Amongst the Bantu the so-called psycho-somatic diseases are rare, and possibly this is the reason why hypertrophic pyloric stenosis is seldom encountered.

That the condition is congenital now appears unlikely, and Wallgren ('46) showed that 5 male neonates who later developed clinical and typical radiological signs of pyloric stenosis, had pyloric canals which were completely normal radiologically shortly after birth. Pyloric stenosis is extremely rarely found at post-mortem on prematures and stillbirths (Nicholson, '53).

The work of McKeown, McMahon and Record ('51a, '51b, '52) has shown that post-natal environment is important in the aetiology. A great change is taking place in the environment of the South African Bantu people. There is a shift to the cities, and here all the strains and stresses of Western European Civilisation are found. The standard of living is being raised, and education, including university education, is becoming available on a rapidly increasing scale. If such environmental factors are responsible for the appearance of the disease in American Negroes, an increase in the incidence of hypertrophic pyloric stenosis, at any rate in the urban Bantu population, may be anticipated in South Africa.

SUMMARY

(1) A case of hypertrophic pyloric stenosis in a South African Bantu infant, confirmed at operation and believed to be the first recorded is reported.

(2) Figures for the incidence of this disease in Johannesburg in 1953-1954 are given, and discussed, and it is concluded that pyloric stenosis is extremely rare in the urban Bantu.

(3) The apparent increase of this disease in the American Negroes is mentioned, and it is suggested that environmental and psycho-somatic factors may be responsible.

(4) It is suggested that an increase in the incidence of pyloric stenosis may be anticipated in the urban South African Bantu.

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THE INCIDENCE OF SIX ANOMALIES OF THE TEETH AND JAWS *

BY MEYER KLATSKY

THE anthropological division of the American Museum of Natural History, New York, is a repository of large collections of ancient and modern skulls suitable for the study of the incidence of dental anomalies. I have chosen 25 groups for whom large numbers of suitable skulls were available and have examined a total of 8,328 skulls. I have investigated six anomalies of the jaws and teeth, namely, torus palatinus, torus mandibularis, supernumerary teeth, naturally missing teeth, reduced teeth, and impacted teeth. I duly recorded each one of the above anomalies, when found in a skull, and present herewith a general summary (tables 1 and 2).

TORUS PALATINUS

Torus palatinus is an abnormal osseous growth in the midline of the hard palate. It may vary in size and form and, while it is nonpathologic, it may interfere with the fitting of a denture when such is required. In recording this, as well as the other anomalies, I eliminated all indistinct and doubtful cases, confining the count to only well developed structures and abnormalities. I found torus palatinus in 18 of the 25 groups examined, totalling 482 cases. It has great prevalence among non-Europeans, but it also affects some Europeans. I found 24 cases of torus palatinus in the 493 German skulls, 60 cases in the 932 Hungarian skulls, and 173 cases in the 1200 Austrian skulls which I examined.

In reporting on torus palatinus, Berger ('52) stated that "it was

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* Abstracts of this paper were presented before the New York Section of the International Association for Dental Research, February 28, 1956 and before the 25th Annual Meeting of the American Association of Physical Anthropologists in Chicago, April 8th, 1956.

TABLE 1

Incidence of jaw and tooth anomalies within groups

GEOGRAPHIC GROUP	NO. OF SKULLS	TORUS PALATINUS	TORUS MANDI-BULARIS	SUPER-NUMERARY TEETH	MISSING TEETH	REDUCED TEETH	IMPACTED TEETH
New Britain	230	0	0	3	25	18	1
Egypt	485	0	0	2	86	15	7
Australia	50	1	0	0	3	3	0
China	52	0	0	0	4	0	0
Asia Minor	300	6	0	0	12	3	6
India	94	0	0	2	16	4	1
Greece	343	5	0	0	10	2	1
Malay Peninsula	94	0	0	0	4	0	0
Germany	493	24	0	2	55	5	10
Hungary	932	60	0	3	113	14	14
Austria	1,200	173	1	5	128	0	23
Peru	430	9	0	2	58	5	11
Eskimo	222	21	18	0	39	14	2
British Columbia	540	44	13	1	55	5	10
Bolivia	875	46	5	4	94	4	6
Mexico	616	11	6	5	104	8	28
Alaska & Aleutian Islands	50	12	3	0	8	5	0
Washington	200	22	0	3	14	3	5
Oregon	61	7	0	0	6	0	0
Kentucky	83	0	0	2	3	3	3
Utah	200	17	8	2	20	0	6
California	32	5	1	0	7	3	0
Colorado	64	1	3	0	4	2	3
Arizona	232	11	12	2	21	6	11
New Mexico	450	7	19	3	58	7	9
TOTALS	8,328	482	89	41	947	129	157

TABLE 2

Distribution of tooth anomalies

		SUPERNUMERARIES	MISSING	REDUCED	IMPACTIONS
Central incisors	upper	21	0	0	*
	lower	2	2	1	0
Lateral incisors	upper	5	33	16	*
	lower	1	0	0	0
Canines	upper	0	1	0	38
	lower	0	1	0	8
Permolars	upper	3	2	0	1
	lower	3	2	0	0
Third molars	upper	—	571	94	30
	lower	—	335	15	48
Fourth molars	upper	3	—	—	—
	lower	3	—	—	—

* 32 in upper incisor region including many supernumeraries.

not clear whether the growth is a developmental anomaly, exostosis, or whether it is an osteoma in the oncologic sense." The consensus among geneticists is that torus palatinus is an abnormality of hereditary nature. Lasker ('47) found only one instance of a discordant pair among 13 pairs of homozygous twins. He also suggested that torus palatinus resulted from "an autosomal dominant inheritance in some instances" (Lasker '50).

TORUS MANDIBULARIS

Torus mandibularis is a bony growth on the lingual surface of the lower jaw usually found bilaterally in the premolar region. It may vary in size, often extending far into the molar area, and it may also be found only unilaterally. Torus mandibularis occurs less frequently than torus palatinus. I found this anomaly in only 11 of the examined groups, notably the Eskimos, the Aleutian Islanders, and some of the American Indian tribes, a total of 89 cases. Weidenreich ('36) called attention to the occurrence of this trait in Sinanthropus mandibles. While torus mandibularis and torus palatinus may be found in the same specimen, in most of the cases they are dissociated and must be considered as separate entities. Hrdlička ('40) and Hooton ('18) suggested the occurrence of these tori as being caused by the hyperfunctional activity of the masticatory apparatus, which is characteristic of many non-Europeans, but some geneticists classify torus mandibularis, like torus palatinus, among the hereditary abnormalities.

SUPERNUMERARY TEETH

The occurrence of supernumerary teeth was investigated and reported by many dentists and anthropologists including Black ('09), Bolk ('14), Stafne ('32), and others. Colyer ('36) made an extensive study of this and other anomalies in the animal kingdom. Reporting on supernumerary teeth in the primates, Colyer found 147 extra teeth in a total of 11,042 skulls which he examined, giving a percentage of 1.3. This is a much higher percentage than most investigators found in the human mouth, even exceeding the highest estimate in the human given by Stafne ('32). Stafne examined 48,550 patients with the use of the X-ray, and found 441 cases of one or more supernumerary teeth, an incidence of 9.1 per 1,000, or one for every 110 persons.

I found only 41 supernumerary teeth in a total of 8,328 skulls examined. However, this low count may be accounted for by the many broken and edentulous maxillary and mandibular specimens in the collection. These, while suitable for the study of other anomalies, proved to be inadequate for an exact count of supernumerary teeth. Stafne's results must therefore be accepted as the more conclusive.

What causes supernumerary teeth? In the past, this phenomenon was explained as an indication of atavism, or the recurrence of characters of remote ancestors, in conformity with the theory of recapitulation which was advanced by Haeckel many years ago (1875), implying that phylogeny anticipates ontogeny, and that adult ancestral stages are automatically pressed back into the individual development of later descendants. This theory has been disproved by de Beer ('51) and others who have shown that phylogeny is not the cause, but rather the result of ontogeny. Abnormal characters first appear in the individual as mutations. The mutant genes responsible for such dental anomalies as supernumerary teeth, and others, may become fixed, establishing themselves in the human race as well as the rest of the animal kingdom. The hereditary nature of the above and many other dental anomalies was pointed out by Keeler ('35), Lasker ('50), and other researchers.

MISSING TEETH

The incidence of genetically missing teeth is greater in man than in other animals. In making comparisons of missing with supernumerary teeth among the anthropoids, Colyer ('36) reported: in the gorilla, 4.4% of extra teeth and 0.6% of absent teeth. In the chimpanzee, he found 2.9% of extra teeth as compared with 1.6% of absent teeth. In the orang-utan, 6.8% of extra teeth and 2.4% of missing teeth. In the gibbon, 0.7% of extra teeth and 3.6% of absent teeth. This shows that, with the exception of the gibbon, where extra teeth are very rare, anthropoids show a small proportion of absent to supernumerary teeth. The opposite is the case in man, the proportion of naturally missing teeth being far greater than that of supernumerary teeth.

In my examination I found genetically missing teeth in all the 25 groups, a total of 947 teeth (see table 1). It would be unscientific, however, to apply the above as the exact statistical proportion of missing teeth to all mankind. In the final tabulation of his animal studies, Colyer omitted the cases showing absence of teeth from his table "as their determination is, in many cases, rendered difficult owing to the possible loss of the teeth from injury." The clinical study of missing teeth in the human is not any easier because of the frequent loss of teeth due to caries or other causes, making it difficult to distinguish between naturally and artificially missing teeth. This acounts for the discrepancies encountered in the reports on studies of this nature by different investigators.

The frequency of missing teeth, especially those of third molars and upper lateral incisors, in the mouth of man attracted the attention of numerous researchers, including Schultz ('32), Goldstein ('32), Hellman ('36), Dahlberg ('37), Montagu ('40), Brekhus *et al.* ('44), Pedersen ('47), Mandeville ('49), Rushton ('53), and others. It is within the realm of the genetically minded medical man and dentist to investigate the subject more thoroughly. Is the phenomenon of naturally missing teeth an abnormal trait or a different variation within the range of normality? Is this deviation from the normal tooth formula due to a reshuffling of normal genes, or are mutant genes responsible for it? The geneticist Stern ('49) points out that "the difference between normal and abnormal is particularly significant from the point of view of medical men and those psychologists who are interested in the inheritance of mental defects; the differences between normal variants concern the anthropologists and those psychologists who investigate the normal variability of mankind."

Some geneticists tend to consider absent teeth as variations within the limits of normality. For example, in their book, *Human Heredity*, Neel and Schull ('54) are discussing certain variations in organisms which may be influenced by both heredity and environment. According to these authors variation in the number of bristles in the *drosophila* may be due to such environmental factors as differences in diet or temperature. Proceeding to compare variations in the number of bristles in flies with variations in the number of teeth in man, they make the following statement: "Some individuals lack one or more incisor teeth, others lack third molars, and some few develop no teeth at all. These are in part inherited but are in part due to the occurrence of certain types of illness or dietary deficiencies at certain periods in the development of the tooth."

By partly attributing tooth absence to environmental factors, the authors automatically imply that this variation belongs more to the domain of modifications than of mutations. In differentiating these terms, the geneticist Schmalhausen ('49) says: "Mutations are always new acquisitions of the organism, while modifications are merely a superstructure or a new version of the already existing organization." Dental deficiencies like complete or partial absence of teeth have been studied by Brodie *et al.* ('42), Brekhus *et al.* ('44), Grant and Falls ('44), Ellis ('46), Sealey ('46), and others. They all seem to agree that anodontia and oligodontia are caused by a detrimental mutant gene for the sex-linked anhidrotic ectodermal dysplasia. Individually missing teeth undoubtedly are also a product of genetic changes originating as phenotypic expressions of mutant genes.

REDUCED TEETH

Reduction in the size of some teeth is also a common occurrence. The teeth and their development are controlled by a gene complex, an aggregate of numerous genes. Some of these presumably give expression to the dental apparatus as a whole, while others control each tooth separately, as every tooth is an independent organic unit. The pattern, size, and shape of each tooth are also regulated by different genes and gene modifiers. Tooth quantity is governed by multiple factors. It is therefore reasonable to believe that when a phenotypic change in the size or form of a tooth occurs it must be due to an alteration in one or more of the gene modifiers, as distinguished from those genes which are responsible for the formation of the tooth.

Some teeth are more susceptible to reduction than others. Dahlberg ('49) divided the dental formula into stable and variable teeth. The lower central incisors, upper lateral incisors, the second premolars, and second and third molars are the unstable teeth. They often develop in reduced size and abnormal shape. The degree of reduction of these teeth may also vary.

In examining the skulls, I only recorded those cases which showed extreme reduction, *i.e.*, limiting myself to peg-shaped teeth. I found a total of 129 such teeth in my collection (see tables). Other researchers who included slight abnormalities naturally found much greater numbers of reduced teeth in the human mouth.

IMPACTED TEETH

Dental impactions constitute a problem of major practical importance to the dentist. Much has been written on the diagnosis, prognosis, and surgical removal of unerupted or impacted teeth, but very little is known about their etiology. The sparse material published on the causes of dental impactions is more of a speculative than of strictly scientific nature. There is a common belief that the failure of some teeth to erupt is characteristic of modern man with his small jaws, which do not allow ample space for all the teeth to erupt. But tooth impactions do occur in large as well as in small jaws. There is a great incidence of this anomaly among ancient and non-European peoples with fully developed, compact jaw-bones and teeth. Ancient peoples and modern tribes, such as the Egyptians and the American Indians, who are known for their well-developed masticatory organs show a high incidence of impacted teeth (see tables). The prehistoric Mousterian youth had an impacted lower left permanent canine.

Elsewhere ('53), I have reproduced dental roentgenograms of an 82 year old woman with both her upper canines impacted. Her jaw-bones are fully developed. She still retains most of her good teeth, and large natural spaces between the upper lateral incisors and premolars that could well accommodate those canines are much in evidence. In spite of all this her canines still remain unerupted.

The nearest approach to the solution of this problem was reported two decades ago by Hellman ('36), a dental anthropologist. He found that the occurrence of tooth impaction was generally associated with retardation of the growth of the face. He coupled third molar impactions with their absence, linking both phenomena to the process of organic evolution. He concluded that "there is a trend in human evolution to suppress the third molar teeth, and that this occurs in two ways: one is by delaying their eruption indefinitely and the other by eliminating them entirely." He does not hazard an opinion whether tooth impaction is caused by environmental or by hereditary factors, but by linking it with the physiological process of growth and development he seems to me automatically to relegate it to the domain of heredity. If we are to associate tooth impaction and tooth absence with evolution we must necessarily realize that both abnormalities are of genetic nature.

So far, there has been very little evidence published to show the true genetic nature of dental impactions. Most experimentation in genetics has been performed on toothless animals and plants. The human being is a poor subject for this kind of experiment. The only mention of tooth impaction as being associated with genic abnormality is by Snyder ('51), who reported: "In cattle, for example, we have discovered in our laboratory a recessive gene which is lethal. In the homozygous condition it produces calves with an abnormal lower jaw, in which the lower teeth are impacted." All indications are that tooth impaction, like the other dental anomalies discussed above, are the result of similar genetic alterations.

SUMMARY

The human teeth and jaws are subject to various anomalies or abnormalities of genetic origin. The incidence of six anomalies which lend themselves most readily to study by means of skull examination was studied. A total of 8,328 skulls belonging to 25 geographically arranged groups were investigated. Torus palatinus was found in 18 of these groups, both ancient and modern, totalling 482 palates. Torus mandibularis was found in 89 mandibles of 11 groups, mostly non-Europeans. The occurrence of supernumerary teeth was limited to 14 groups, totalling 41 teeth. A total of 947 naturally missing teeth, mostly third molars, were found among all the 25 groups. Reduced teeth were found in 20 groups, totalling 129 teeth. One hundred fifty-seven impacted teeth, mostly third molars and canines, were found in 19 groups, affecting Europeans and non-Europeans alike.

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BOOK REVIEWS

Medical Research: A Midcentury Survey. Edited by ESTHER E. LAPE. Vol. I. American Medical Research. xxxii + 765 pp. Vol. II. Unsolved clinical problems. xxxii + 740 pp. Little, Brown and Co., Boston, for the American Foundation, New York, 1955. $15.00.

It is not a mere coincidence that the adjective "fascinating" has been used by at least two previous reviewers in their evaluation of this publication. For "fascinating" is, in fact, the term that best characterizes this large work. The first volume deals with the principles and practice of medical research, and is particularly relevant for students of human biology. The introduction, describing why and how the study was made, is followed by four sections entitled Medical research in perspective of current biological, chemical, physical and mathematical science, The current trends and current problems in biological and medical research in the United States, The research agencies, and Clearing results and controlling products of medical research.

There is such a wealth of information contained in these 700-odd pages that practically no relevant aspect of broadly conceived medical research or of medical education is not covered. Yet the sound basic philosophy underlying the presentation of details seems to be still more important. The book develops the thesis that medical progress is the outcome of research, and that research on fundamental problems generally precedes clinical applications. It is gratifying that such a thesis is so authoritatively defended at this very moment when general interest and financial support for medical research are growing. Research on problems with an immediate, "practical" application is not always the best nor the quickest way to solve the persisting needs of therapy. Research on the basic questions, even if they appear to be unrelated at the time to any practical application, is and will be the surest and most rewarding way to foster the progress of medicine.

It is to be hoped that the efforts Esther E. Lape and her staff devoted to compiling these volumes will be rewarded by a better understanding of the nature of the relationship between basic research and medical progress. It is fully appreciated by the workers in the field but it needs wider recognition among medical practitioners, agencies supporting medical research, and general public. Application of the advances made by medical research to the practical problem of providing adequate medical care calls for a maintenance of high standards of medical education, and the volume offers much food for thought and a challenge to medical educators.

We wish to emphasize here our complete agreement with the opinion expressed by Curtis Bok in his foreword to the book that "It is useless to discuss the administrative problem of distributing medical care and the economic problem of paying for it without reference to the central need of having a sufficient number of trained physicians capable of providing a type of medical care that can justify elaborate plans for distributing it and paying for it." It has been the sad personal experience of this reviewer that in some countries the agencies responsible for the organization of national programs of medical care seem to have paid little attention to its "quality."

The second volume deals with the present situation of medical research regarding nine major "unsolved" problems: cancer, infertility, arteriosclerosis, hypertension, rheumatic syndromes, tuberculosis, virus diseases, alcoholism, and schizophrenia. The topics are presented in the form of critical, constructive reviews of the literature and will be useful to those interested in these subjects.

The American Foundation deserves to be commended for this truly magnificent work which will no doubt have profound and long lasting influence on the development of medicine in all of its phases.

FRANCISCO GRANDE

University of Minnesota,
Minneapolis, Minn.

Introduction to Demography. By MORTIMER SPIEGELMAN. xxi + 309 pp. The Society of Actuaries, Chicago, Ill. No price.

Writen as a textbook for actuarial students, this book will have a wide audience among all those who are interested in acquainting themselves with the problems and methods of demography. It is, so to speak, a running-mate to Hugh Wolfenden's *Population Statistics and Their Compilation*, published in 1954 by the University of Chicago Press.

At the outset, the author provides the historical background. He tells us that the first enumeration of a population was made in Babylonia 3,800 B. C. In the second and third chapters he explains the methods of collecting census data and vital statistics, and adjustments for errors.

Chapters four and five are concerned with measures of mortality and the construction of life tables. For intelligent reading of these chapters some previous knowledge of actuarial mathematics is required; however, the numerical examples used as illutrations ease the reader readily into the theoretical considerations. In chapter six the highly complex problem of mortality projection is considered. Here, too, previous knowledge is needed. This chapter is probably the best part of the entire work. In chapter seven Spiegelman deals with the perplexing problems of morbidity statistics. Chapters eight and nine analyze family formation and dissolution, fertility and reproduction.

The balance of the book comes to grip with census areas, internal and international migration (as it affects the United States and Canada) and the estimation of their effects. Some 30 pages are devoted to the analysis of the working population, including unemployment data. In the final chapter methods of population projections and estimates are explained and illustrated. There are some 35 pages of valuable references.

The data referred to by the author are limited mostly to the United States and Canada. Those of us who have concerned ourselves with research requiring population comparisons in different parts of the world would have liked to see a chapter on that subject included. In any case, Spiegelman's book will serve as an excellent reference work for vital statistics specialists abroad since he has included essentially everything that is worthwhile to know about the practices of the United States and Canada in this field.

ERNEST H. KLEPETAR

Mutual Service Life Insurance Company,
St. Paul, Minnesota

The Hypophyseal Growth Hormone: Nature and Actions. Edited by RICHMOND W. SMITH, OLIVER H. GAEBLER, and C. N. H. LONG. 576 pp. McGraw-Hill Book Co., New York, 1955. $12.00.

Advanced seminars, colloquia, or symposia have come to be increasingly popular with scientific men engaged in today's astounding overproduction of research reports in the standard journals of the world. Among agencies responsible for conducting these symposia must be mentioned the Ciba and Macy Foundations, UNESCO, the AAAS, and the so-called Laurentian Conferences. It is to the credit of the staff of the Henry Ford Hospital and the Edsel Ford Institute for

Medical Research that a symposium on the anterior hypophyseal growth hormone was conducted approximately a year ago and its deliberations published within a bare half year period—a record in promptitude.

Ever since the indispensability of the hypophysis for bodily growth was detected, and the prompt resumption of growth produced by the administration of anterior hypophyseal extracts, interest was given the central question of whether such reinvoked growth came from multiple essential constituents or hormones in the hypophysis or from a single specific substance—the so-called growth hormone. This has led to the isolation and purification of the substance designated as growth hormone (somatotropin). Preparations of it confer growth but are free of contamination with other anterior hypophyseal hormones.*

A host of unsolved problems as to the intervention of the growth hormone in normal and disordered metabolism are painfully evident in the present monograph, but this is just what every good survey should do. If exploration of the participation of the growth hormone in carbohydrate and protein metabolism is under way, similar effort as regards fat and even water and electrolyte metabolism has not received adequate attention. Specific metabolic synergisms and antagonisms of the growth hormone, especially its relations with ACTH, are not adequately treated. On the other hand, the chapters by Frank L. Engel on ketogenesis and by Honor B. Fell on hormonal effects in tissue are refreshing, and that on the comparative physiology of the pituitary by Alfred E. Wilhelmi perhaps the most provocative contribution in the book. The "Closing Remarks" by C. N. H. Long are themselves an admirable summary.

In conclusion, it may be said that a great body of scientific information as to the nature of the growth hormone and its participation in many phases of metabolism has now been secured and is here recorded. The monograph will hence be of inestimable value to research workers in this and related fields.

HERBERT M. EVANS

University of California,
Berkeley, California

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* These results have not hitherto been applicable to cases of undergrowth in man, but the reason for this now appears to this reviewer to be clear and is to be sought in the report by Knobil and Greep (Anat. Rec., *124*: 320 (Feb. 1956)) of the successful provocation of increased growth in young monkeys by the administration of a somatotropic preparation made from monkey pituitaries whereas highly purified and potent somatotropin of bovine origin had proven inefficacious.

BOOK NOTICES

The French Bibliographical Digest. Edited by The Cultural Division of the French Embassy. Part I. iii + 63 pp., Part II. iii + 88 pp. French Embassy, New York City, 1956. (no price). The Digest is intended as a bridge between French scientists and research workers abroad. The introductory section consists of a list of French periodicals, scientific societies and official agencies, and C. Lévi-Strauss' brief essay on "Anthropology in France Today." The core of the volume are abstracts of publications (1947-1955) in physical anthropology and prehistoric archeology (Part I) and in regional ethnography and archeology (Part II).

Mental Disorders in Later Life. Edited by Oscar J. Kaplan. ix + 508 pp. Stanford Univ. Press, Stanford, 1956. $7.50. A collection of 19 essays, first published in 1945 and now expanded and brought up to date, documenting the editor's conviction that "only through the close collaboration of psychiatrists, statisticians, physiologists, sociologists, and psychologists can we obtain the fullest measure of triumph over these afflictions which today account for more than a fourth of all first admissions to American mental hospitals."

Portraits from Memory. By Richard B. Goldschmidt. ix + 181 pp. Univ. of Washington Press, Seattle, 1956. $3.50. Delightful essays which grew out of informal seminar talks on old times in zoology and on outstanding zoologists known by the author.

Present-Day Psychology. Edited by A. A. Roback. xiv + 995 pp. Philosophical Library, New York, 1955. $12.00. An outgrowth of the editor's *History of American Psychology* (1952), this collaborative survey consists of 5 parts labelled as topical departments (neural function, sensation, perception, etc.), branches (such as child, abnormal and social psychology), phases (including dynamic and clinical psychology), methods (statistics, interdisciplinary approach), and psychological borderlands (including psycholinguistics, esthetics, and psychology of religion). Though uneven and incomplete, the volume portrays a large number of facets of psychology's complex present.

Rank Correlation Methods. By M. G. Kendall. vii + 1956 pp. Hafner Publ. Co., New York, 1955. $5.50. A revised and enlarged edition of the monograph on the analysis of ranked data, covering both practical applications and the underlying theory.

Research Films in Biology, Anthropology, Psychology and Medicine. By Anthony R. Michaelis. xvi + 490 pp. Academic Press, Inc., New York, 1955. $10.00. A unique "Handbook" of scientific cinematography. A critical discussion of the appropriate techniques precedes the accounts of their usefulness in dealing with a particular problem. Attention is drawn to quantitative evaluation and to possible new uses of the techniques. 1500 references.

SOCIETY AND HEALTH. By Walter E. Bock and Jean K. Bock. xviii + 301 pp. G. P. Putnam's Sons, New York, 1956. $4.50. Designed to aid medical-care personnel to understand human behavior in the framework of cultural authropology. Describes the process of acquiring culture and social differentiation within the U. S. cultural setting. The social structure of community leadership and of a hospital, the association between social factors and illness, and the changing scene in medical care are considered.

STARLING'S PRINCIPLES OF HUMAN PHYSIOLOGY. By Charles Lovatt Evans. ix + 1233 pp. (721 illustrations). Lea & Febiger, Philadelphia, 1956. $12.50. A revision of one of the leading textbooks in physiology, with a brief reference to growth and body composition (p. 812). Except for H. Hartridge's section on special senses, the weighty volume has the distinction of being edited by a single hand and mind.

FIFTH ANNUAL REPORT ON STRESS. Edited by Hans Selye and Gunnar Heuser. 815 pp. MD publ., New York, 1956. $20.00. Result of the continued efforts to record and systematize the world literature on stress. Some 5700 publications are considered in the present volume. In addition to the introductory material and Selye's review on "General physiology and pathology of stress," there are 9 special articles focussed largely on hormonal factors.

THE STRUCTURE AND FUNCTION OF SKIN. By William Montagna. 356 pp. Academic Press, New York, 1956. $8.80. A monograph on the microscopic anatomy of the skin, a versatile, heterogeneous organ in which the constituent suborgans have their own cycles of growth and activity. Integrates the findings made in the author's laboratory at Brown University with data from the literature. The fatty layer underneath the dermis is considered only incidentally.

TEXTBOOK OF MEDICAL PHYSIOLOGY. By Arthur C. Guyton. xiv + 1030 pp. W. B. Saunders Co., Philadelphia, 1956. $13.50. Writen expressly for the student, not as a combination of a textbook and a reference work for physiologists, it will be welcome by the audience to which it addresses itself.

TRACE ELEMENTS IN HUMAN AND ANIMAL NUTRITION. By E. J. Underwood. 430 pp. Academic Press, Inc., New York, 1956. $9.50. The first comprehensive survey of trace elements, including iron, iodine and fluorine, from the point of view of their nutritional significance to man and domestic animals.

TREATMENT OF THE CHILD IN EMOTIONAL CONFLICT. By Hyman S. Lippman. x + 298 pp. McGraw-Hill Book Co., Inc., New York, 1956. $6.00. Describes methods applying some features of child analysis to the treatment that can be offered in a medically oriented child guidance clinic. Stresses "total therapy" which requires the combined services of the members of the "psychiatric team, consisting of the caseworker, the clinical psychologist, the child psychiatrist, and recently, the group therapist. Others may also be involved in the therapy, depending on the needs of the child and his parents."

YEARBOOK OF ANTHROPOLOGY. 1955. Edited by William L. Thomas, Jr. xv + 836 pp. Wenner-Gren Foundation for Anthropological Research, New York, 1955. (no price). A selective report on major trends and accomplishments in the broad field of anthropology during 1952-1954. Readers of this journal may be especially interested in J. S. Huxley's guest editorial on "Evolution, cultural and biological" and W. W. Howells' "Universality and variation in human nature."

CURRENT ANTHROPOLOGY: A supplement to Anthropology Today. Edited by William L. Thomas, Jr. xii + 377 pp. The Univ. of Chicago Press, Chicago, 1956. $3.50 (paper) and $5.00 (cloth). Part I of the Yearbook (see above), reprinted as a separate volume.

JOSEF BROŽEK

University of Minnesota,
Minneapolis, Minesota

INDEX TO VOLUME 28

Abraham, S., 203-16
Adults, body measurements of, 118-21
Age—and adult weight standards, 136-7, 183; and ash weight of bones, 149-50; and body height and weight, 182, 192; at menarche, 393-406
Age distribution—in an African village, 328-9
Allometry, 154-73; as a measure of differences in great apes, 43-58

Behnke, A. R., on overweight, 204; on lean body mass, 157, 291, 293
Biester, A., 189-202
Blood groups, ABO, and sex ratio, 20-42
Body build—and body weight, 141-45; and menarche, 400-4; and mortality, 220-1, 227-8; in deaf mutes, 312-3
Body composition in—adolescence, 269; children, 262-9, 289-308; fetus, 257-9; mammals, 253-73; men, 165-76; women, 260-2
Body measurements—of adults, 118-21, 126-31; of children, 121-3, 232-52; of composition, methods, 120-1, 131-5, 146, 165-9, 233-7, 253-7, 407-13
Body mechanics, 67-92
Body weight—and body build, 141-5; and mortality, 217-31; control, 274-5; in Canada, 177-88; of women, 197 ff.; standard, 126-30
Brewer, W. D., 189-202
Brožek, J., Book Notices, 104-6, 286-8, 390-2, 433-5; Book Reviews, 94-6, 278-80, 283-4; Physique and Nutritional Status of Adult Men, 124-40
Buskirk, R. E., 100, 101

Children, body measurement of, 121-3, 232-52, 294, 297, 304; deaf mute Japanese, 309-15
Cohen, B. H., and B. Glass, ABO Blood Groups and the Sex Ratio, 20-42
Coon, C. S., 376-8

Dean, R. F. A., 252
Demography, 430-1; fundamental law of, 1-19; of a Dinka village in Africa, 323-49
Dempster, W. T., 67-92
Diet and menarchial age, 397, 399
Disease—and obesity, 203-6; cancer, 96-8; mental, and migration, 350-64

Environment—cold, 100-1; influence on life, 1-19; social, influence on menarcheal age, 401-2
Evans, H. M., 431-2
Evolution, human, 376-8

Fancher, H. L., Occupation and Sex Ratio of Offspring, 316-22

Fat—as reserve, 124-5; content of body, 298-301; subcutaneous, thickness, 120-1, 131-8, 154-64, 165-76, 182, 195, 198, 205-11, 232-50, 407-13
Fertility, 98-9, 333-5, 340-1
Fraccaro, M., 378-9
Frankel, T., 165-76

Garn, S. M., Fat Thickness and Growth Progress During Infancy, 232-50, Measurement of Subcutaneous Fat, 407-13
Gaughran, G. R. L., and W. T. Dempster, Analysis of Pushes and Pulls, 67-92
Genetics—and demography, 342-6: and evolution, 376-8: and metabolism, 101-2; biochemical, 102-3; medical counseling in, 378-9
Giles, E., 253-73; Cranial Allometry in the Great Apes, 43-58
Glass, B., 20-42
Gorman, E. L., 407-13
Grande, F., 277-8, 429-30
Greaney, G. R., 232-50
Griffiths, J., Pyloric Stenosis in South African Bantu, 414-9
Grigg, E. R. N., Fundamental Law of Life; the Time Factor (Relativity) in Biological Phenomena, 1-19
Grossman, M. I., 165-76, 281-2
Growth—allometric, in the chimpanzee, 46-8; and fat thickness, 232-52; at adolescence, 387-9; hormone, 431-2; in African children, 252; in man and animals, 253-73; methods of study of, 292

Hair color, 59-66
Hartung, F. E., 93-4
Hawthorne, B. E., 189-202
Height-weight—indexes, 125; standards, 183, 218-20
Howells, W. W., 109
Hunt, E. E., Jr., 383-5, and E. Giles, Allometric Growth of Body Composition in Man and Other Mammals, 253-73
Hutchinson, M. B., 189-202

Keys, A., Recommendations Concerning Body Measurements for Characterization of Nutritional Status, 111-23
Kelly, H. J., 289-308
Kihlberg, J., and K. Koski, Dental Statistics, 365-75
Kikkawa, H., Hair Color and Metals in Human Hair, 59-66
Klatsky, M., Anomalies of the Teeth and Jaws, 420-8
Klepetar, E. H., 430-1
Kornfeld, W., 251-2
Koski, K., 365-75
Kralj-Čerček, L., Age at Menarche, 393-406
Krogman, W. M., 381-2
Kurlander, A. B., S. Abraham and J. W. Rion, Obesity and Disease, 203-16

La Barre, W., 93-4
Lasker, G. W., 385-7

Macy, I. G., and H. J. Kelly, Body Composition in Childhood, 289-308
Malzberg, B., Migration and Mental Disease, 350-64
Marks, H. H., Body Weight: Facts from Life Insurance Records, 217-31
Mayer, J., 284-5
Méndez, J., 282-3
Mental disease—and culture, 379-81; and migration, 350-64
Menarche, age at, 393-406
Migration and mental disease, 350-64
Montagu, A., 98-9
Mortality—and overweight, 217-31; from infections and neoplastic diseases, 12-5; in African villages, 335-6, 338-40, 346
Muscle—breadth in calf, 233-5; breadth in upper arm, 128; forces in pushes and pulls, 67-92

Negro, American—measurements of women, 194-6; pyloric stenosis in, 416-7; relation of obesity to heart disease and hypertension in, 203-16; skinfold measurements of, 155-8
Newman, R. W., Skinfold Measurements in Young American Males, 154-64

Obesity and disease, 203-16
Ogilvie, G. F., 177-88
Ohlson, M. A., A. Biester, W. D. Brewer, B. Hawthorne and M. B. Hutchinson, Anthropometry and Nutritional Status of Adult Women, 189-202

Pascale, L. R., M. Grossman, H. Sloane and T. Frankel, Skin Folds and Body Density in 88 Soldiers, 165-76
Passmore, R., 274-5
Pett, L. B., and G. F. Ogilvie, The Canadian Weight-Height Survey, 177-88

Racial differences in—body fat, 157-8; pyloric stenosis, 414-9
Reed, S. C., 101 f., 102 f.
Rion, J. W., 203-16
Roberts, D. F., Demography in a Dinka Village, 323-49

Schermerhorn, R. A., 379-81
Sex ratio—and occupation of parents, 316-22; in persons of different blood groups, 20-42
Silverman, F. N., 387-9
Skinfolds, 137; in Canadians, 182, 186; in Colored of Cape Town, 135; in firemen, 134; in Sardinians, 135; in U. S. Army men, 154, 170; of abdomen, 167, 205; of arm, 120-1, 167, 182, 205; of chest, 167, 407-13; subscapular, 121, 205; versus x-ray, 407-13
Sloane, H. S., 165-76
Statistics, dental, 365-75

Teeth—anomalies, 422-7; caries of, 369-71
Trotter, M., Variable Factors in Skeleton Weight, 146-53

Wedgwood, R. J., 275-7
Welham, W. C., 204
Wenger, M. A., 96-8
White, R. M., Body Build and Body Weight in 25-Year-Old Army Men, 141-5

X-rays, soft tissue, 121, 233, 407-9

Yamaguchi, B., Deaf-Mute Boys, 309-15
Young, R. W., 232-50

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CONTENTS

No. 1, February, 1956

PAGE

Essay on a Fundamental Law of Life: The Time-Factor (Relativity) in Biological Phenomena........*E. R. N. Grigg* 1

The ABO Blood Groups and the Sex Ratio........*Bernice H. Cohen and Bently Glass* 20

Cranial Allometry in the Great Apes........*Eugene Giles* 43

Relation Between Hair Color and Metals in Human Hair..*Hideo Kikkawa* 59

Force Analyses of Horizontal Two-Handed Pushes and Pulls in the Sagittal Plane........*George R. L. Gaughran and Wilfred Taylor Dempster* 67

Book Reviews........ 93

Book Notices........ 104

No. 2, May, 1956

Introduction........*W. W. Howells* 109

Recommendations Concerning Body Measurements for the Characterization of Nutritional Status. Committee on Nutritional Anthropometry, Food and Nutrition Board, National Research Council, *A. Keys*, Chairman........ 111

Physique and Nutritional Status of Adult Men........*Josef Brožek* 124

Body Build and Body Weight in 25-Year-Old Army Men..*Robert M. White* 141

Variable Factors in Skeleton Weight........*Mildred Trotter* 146

Skinfold Measurements in Young American Males....*Russell W. Newman* 154

Correlations Between Thickness of Skinfolds and Body Density in 88 Soldiers........*Luke R. Pascal, Morton I. Grossman, Harry S. Sloane and Toby Frankel* 165

The Canadian Weight-Height Survey........*L. B. Pett and G. F. Ogilvie* 177

Anthropometry and Nutritional Status of Adult Women........*Margaret A. Ohlson, Alice Biester, W. D. Brewer, Betty E. Hawthorne and Marie Bohland Hutchinson* 189

Obesity and Disease........*Arnold B. Kurlander, Sidney Abraham and J. Wallace Rion* 203

Body Weight: Facts from Life Insurance Records......*Herbert H. Marks* 217

Fat Thickness and Growth Progress During Infancy..*Stanley Marion Garn with the assistance of Georgia R. Greaney and Richard W. Young* 232

Comments........*Werner Kornfeld* 251

PAGE

Comments . . . . *R. F. A. Dean* 252

Allometric Growth of Body Composition in Man and Other Mammals . . . . *Edward E. Hunt, Jr. and Eugene Giles* 253

Book Reviews 274

Book Notices 286

No. 3, SEPTEMBER, 1956

Body Composition in Childhood with Reference to *in vivo* Chemical Analysis of Water, Fat, and Protoplasmic Mass . . . . *Icie G. Macy and Harriet J. Kelly* 289

Some Physical Peculiarities of Deaf-Mute Boys . . . . *Bin Yamaguchi* 309

The Relationship between the Occupational Status of Individuals and the Sex Ratio of Their Offspring . . . . *Harriett L. Fancher* 316

A Demographic Study of a Dinka Village . . . . *D. F. Roberts* 323

Migration and Mental Disease in New York State, 1939-1941 . . . . *Benjamin Malzberg* 350

On Basic Principles in Dental Statistics . . *Jaakko Kihlberg and Kalevi Koski* 365

Book Reviews 376

Book Notices 390

No. 4, DECEMBER, 1956

The Influence of Food, Body Build, and Social Origin on the Age at Menarche . . . . *Lea Kralj-Čerček* 393

Comparison of Pinch-Caliper and Teleroentgenogrammetric Measurements of Subcutaneous Fat . . . . *Staley M. Garn and Edward L. Gorman* 407

Hypertrophic Pyloric Stenosis in the South African Bantu . . *Joan Griffiths* 414

The Incidence of Six Anomalies of the Teeth and Jaws . . . . *Meyer Klatsky* 420

Book Reviews 429

Book Notices 433

Index 437

INFORMATION FOR CONTRIBUTORS

Human Biology, a record of research, is a quarterly journal devoted to the subject its name implies. It publishes original articles dealing with human genetics, development, growth, reproduction and aging, functional anatomy, bio-anthropology, human ecology, population dynamics, etc.

The original manuscripts, typed double-spaced on one side of 8½ x 11 inch paper in complete and finished form precisely as they are to appear, should be sent—packed flat—to the editor, Dr. Gabriel Lasker, Wayne State University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan. It is desirable that a second copy be included in order to expedite prompt consideration, and that an additional carbon copy and copies of all illustrations should be retained by the author.

Where possible, illustrations should be made for reproduction as line engravings, hence drawn in India ink as boldly as possible. Lettering must remain legible after figures are reduced to fit on 4¼ x 6¾ inch pages (letters 1½ to 2 mm high after reduction are adequate). Figures should be numbered consecutively with Arabic numerals. Tables should be numbered independently from 1 up, and both figures and tables should have captions. When the amount of tabular and illustrative material is judged to be excessive or unusually expensive, authors may be requested to pay the excess cost. Galley proofs will be sent to the author and must be returned promptly; when the author makes substantial departures from copy, the cost will be charged to him. Three copies of an abstract (not to exceed 225 words) should be submitted when the proof is returned. One will be sent to the editor of *Biological Abstracts.*

References in the text to the literature should be made by using the author's name followed by the year of publication: " Studies of Garn and Saalberg ('53) . . ." At the end of the article, under the heading "LITERATURE CITED," full references with titles and inclusive page references should appear (double spaced) in alphabetical order of the authors' names: " GARN, S. M. AND J. H. SAALBERG 1953 Sex and age differences in the composition of the adult leg. Human Biol., *25:* 144-153."

Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the proof has been returned to the press.

Human Biology

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VOLUME 28 DECEMBER 1956 NUMBER 4

CONTENTS

THE INFLUENCE OF FOOD, BODY BUILD, AND SOCIAL ORIGIN ON THE AGE AT MENARCHE. *Lea Kralj-Čerček* 393

COMPARISON OF PINCH-CALIPER AND TELEROENTGENOGRAMMETRIC MEASUREMENTS OF SUBCUTANEOUS FAT. *Stanley M. Garn and Edward L. Gorman* 407

HYPERTROPHIC PYLORIC STENOSIS IN THE SOUTH AFRICAN BANTU. *Joan Griffiths* 414

THE INCIDENCE OF SIX ANOMALIES OF THE TEETH AND JAWS. *Meyer Klatsky* 420

BOOK REVIEWS 429

BOOK NOTICES 433

INDEX 437

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